Design Engineering

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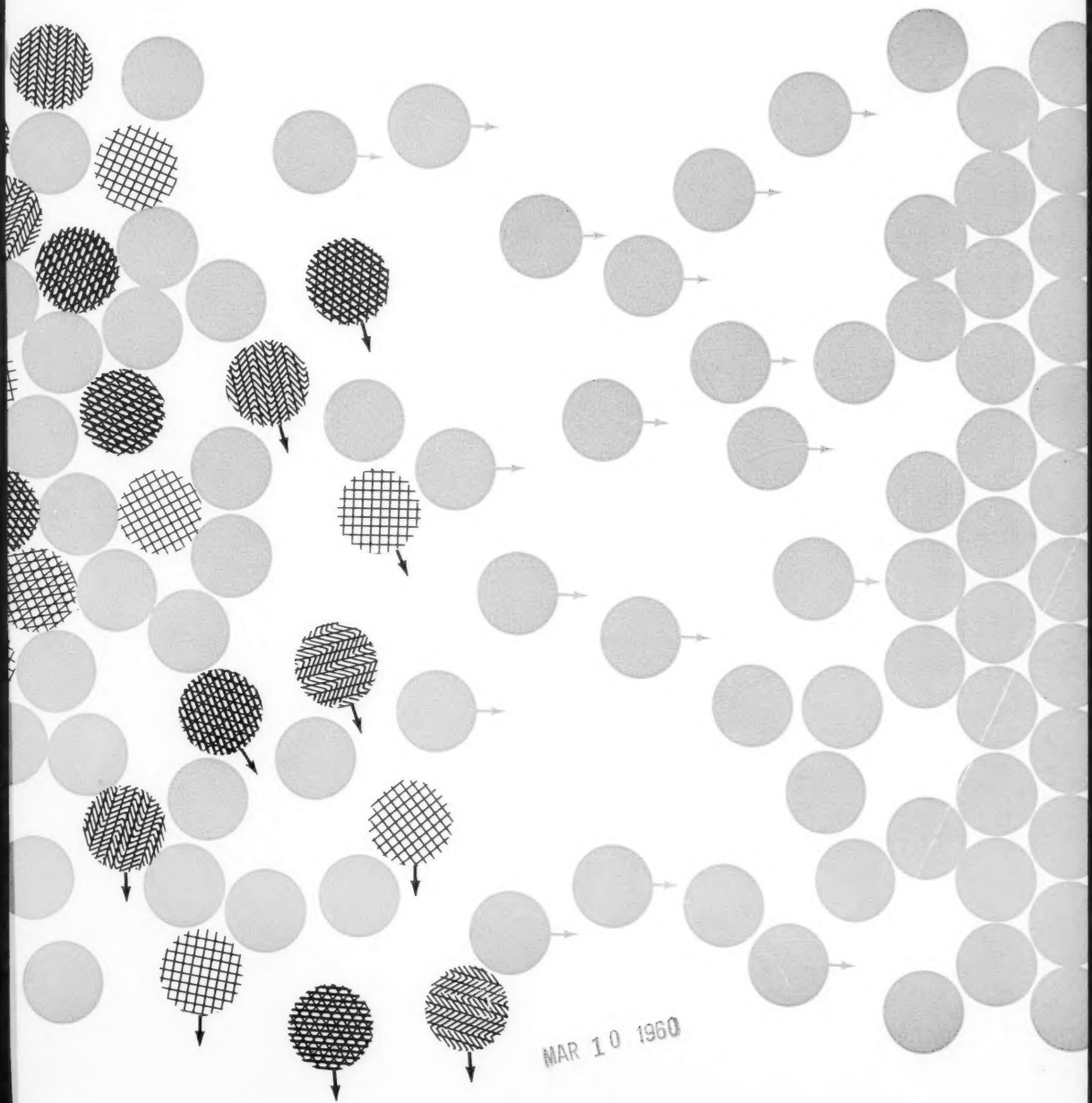

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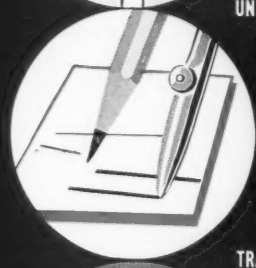

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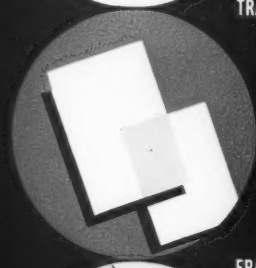

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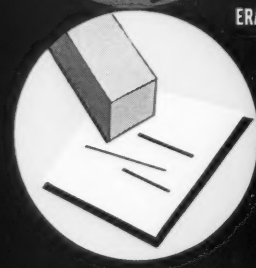

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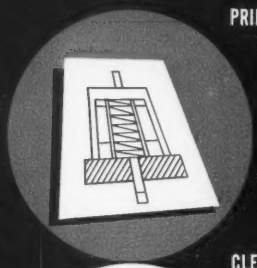

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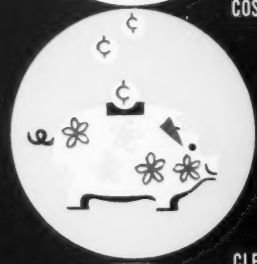

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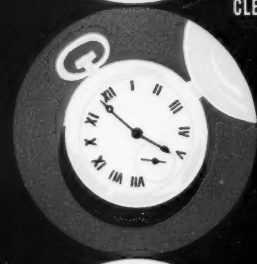

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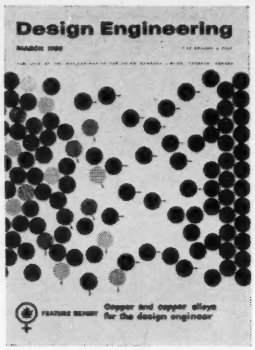

Design Engineering

Vol. 6 **MARCH 1960** No. 3

This month's cover

Ray Wardell tells us on page 47 that Canada's copper is refined by the electrolytic process—which produces metal of very high purity. We don't know how pure you would say this month's cover is, but in any case, it represents the copper-refining chemical reaction. John Bellinger, a Maclean-Hunterite did the art work.

★ ★ ★

Design Engineering

MEMBER

CCAB

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Reprints available

Reprints of the Feature Report which appeared in the February Issue on "The design and drafting office" are available. Price 25c each. Send your orders to Design Engineering, Department K, 481 University Avenue, Toronto 2, Ontario. *Cash with order.*

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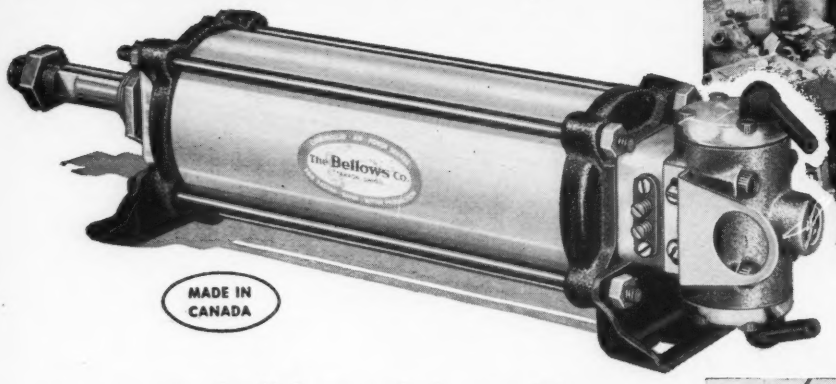

After Neptune Meters, Ltd., Toronto, equipped its turret lathes with Bellows Air Motors, one man was able to operate two machines, production rose 2½ times.

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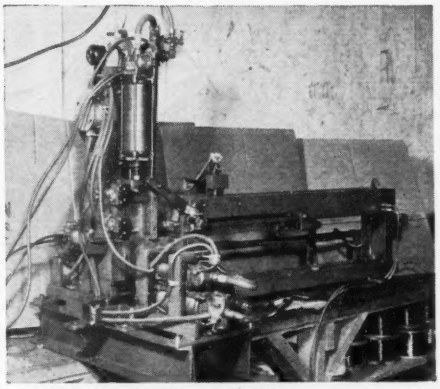
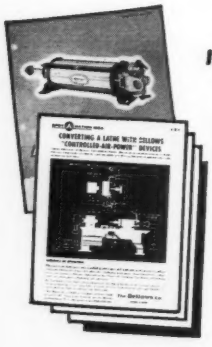


Built around Bellows Air Motors, this wire forming machine automates a slow, tiresome operation for Wilson Electric, Winnipeg reconditioner of motors and generators.



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Metalwork among the monkeys
In 1940 Queen's University graduated a metallurgist called **Walter H. Irwin.** Today he is vp of Canada Metal Co., Ltd., and contributed "Forging is easy with hot-pressed brass". During the intervening period he installed a process for making brass cartridge cases in Oshawa and operated a jungle foundry in Madagascar for the RCN. He is now married and lives in unjunglelike Lorne Park where, we are happy to report, he is very active in community affairs.

Man of many metals and medals
John Allan, who wrote "Initial design dictates final quality" for us, knows his metals. He served his apprenticeship on all phases of bronze, aluminum and gray iron founding in Scotland. He knows the metals that go into medals, too. In Scotland he won both the Surtees gold and silver medals. Allan has been in Canada since 1948 and is now vp and general manager of St. Catharines Brass Works Ltd. More medals for his collection have come from his hobby of ballroom dancing. His favorite partner? His wife, of course.

It took two to write this one
Two young engineers got together to produce "Selection of tube elements." **Gerald Fenwick,** prairie-born but no farmer, he says, is a mechanical engineering graduate of U. of Saskatchewan. He moved to his present company, Unifin Tube Co., in 1956 as chief engineer, in charge of production and engineering in 1957. Fenwick is married and has two children.
Co-author **Roger B. Stotts** is also the father of two children. At present he's with Wolverine Tube and in the last year has developed a new extrusion mandrel for the company's large size base tubing. He has also worked for ALCAN and the "Three Ms". Stotts graduated in 1953 from Queen's University in metallurgical engineering.

Found no fringe benefits in brewery
G. N. Thomas who sent us "For handling corrosives — it's copper" is a product of the British Institute of Engineering Technology. His experience includes work on brewery and distillation plants but he complains that his job was usually done before they started to pump the good stuff through. He came to Canada in 1950 and has been with Canadian Vickers ever since. Thomas is married, has two children, fishes for recreation.

Mr. Copper and Brass himself
The man we got to prepare "Physical Properties of Copper" could almost be described as Mr. Copper and Brass himself. He's **Ray Wardell,** manager of the Canadian Copper and Brass Development Association. Now a Canadian citizen, he comes from England where, in 1940, he won the national award for highest marks in copper theory and practice. After RAF service (bomber pilot in Burma) he was with the Copper Development Association. Came to Canada in 1948 and spent 10 years in the west. Now makes his home in Toronto.

He knows the ways of wire
Keith Alexander, who wrote "Copper is ideal electrical conductor," now enters the ninth year of his romance with wire. He graduated from the University of Toronto in 1951, in ceramic engineering, and has been working with Canada Wire & Cable Co., Ltd., ever since — first as a chemical engineer, currently as magnet wire engineer.

Wardell

Allan and wife

Irwin

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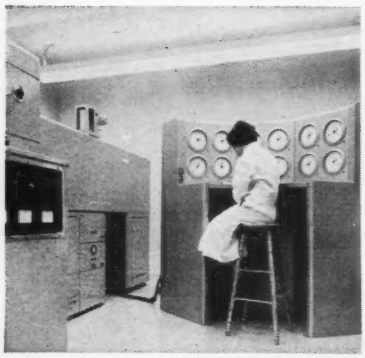
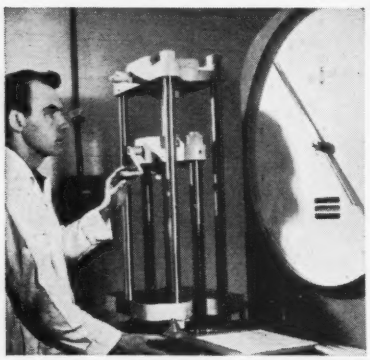


Direct reading spectrometer controls the quality of extrusion billets.



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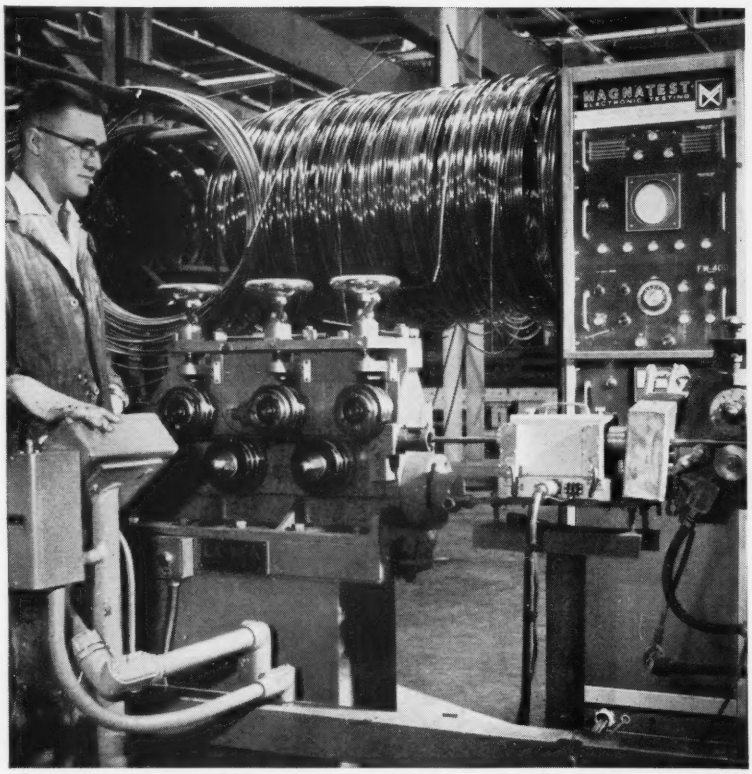

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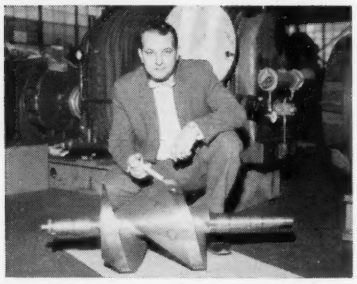
Reports

A news roundup of items of engineering and design interest from the world over

Designer's spin takes prize in founders' contest



This swirl of steel is a winner and the proud fellow showing it off is the man who took the prize home. He's Joseph D. Walls, chief design engineer of spiraxial® compressors for Roots-Connersville Blower. He took second place in the Gray Iron Founders Inc. 1959 design contest. His entry was a redesign of spiraxial® rotors to achieve 41 percent greater displacement with a 29 percent reduction in cost. The former design had forged steel shafts on which were pressed ductile iron rotors. The new unit has integrally cast rotors and shafts that permit smaller hub diameters and correspondingly larger outside diameters in the same cylinder. The result is a reduction in material cost, less machining and shorter assembly time.

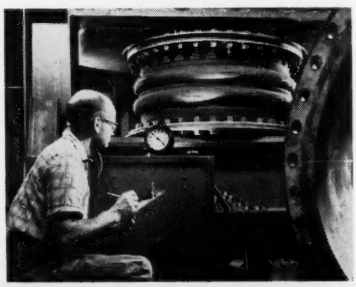
Sensitive secret to probe the North

This instrument is going to take a close look at Canada's North. But first it is going to demonstrate its capabilities in countries around the world. Name of the little fellow is the Lundberg Gradiometer. It's the first airborne gravity gradiometer in the world and was invented right here in Canada by Dr. Hans Lundberg. What's inside? Dr. Lundberg knows, of course, but he's not telling, though he's quite happy to show how it works. What he will tell you is that basically his gradiometer is a sensitive electric balance composed of two substantially similar masses suspended on thin filaments, one above the other, with a variable condenser located near the masses. Masses change their position when flown over density differences. Electronic measurement of the changes identifies the densities.

Zinc die-casting pins and connectors

Here you see a selection of tiny taper pins and connectors. They are the product of an automatic zinc die casting technique developed by Gries Reproducer Corp. These particular connectors will go into Dictaphones but the applications are many and varied: computers, tape recorders, business machines. The units must generally be produced in complex shapes, thin cross sections, close tolerances and in large volume. The die casting technique is said to meet these demands with maximum economy. Connector varieties produced by this method include double receptacles that allow connections to be made from either end, parts cast with predetermined breaking points, parts cast with rivet lugs for mounting separate fasteners and integrally cast bosses that keep receptacles in terminal boards.

Joints in subs stub sleeping sailors' toes

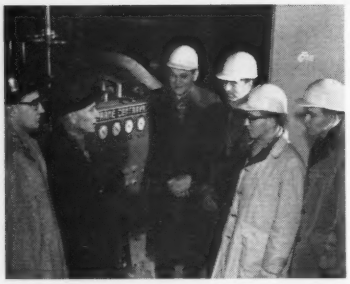


This man is no clock-watcher. He's hydrostatically testing Viton-lined neoprene expansion joints that are designed for use in U. S. Navy nuclear submarines. They are located in exhaust lines carrying turbine steam to condensers. Particular liner was specified because of its freedom from chlorine ions. A special binding process was developed by the Garlock Packing Co., to adhere the material to the carcass of the expansion joints. These are fabricated of neoprene in sizes that include 42 in. ID x 24 in. face-to-face and 26 in. ID x 24 in. face-to-face. They are asbestos reinforced with internal steel body rings. Now you know why sub sailors complain about small bunks — design engineers use up all the space.

Canadian teleprinter for world markets

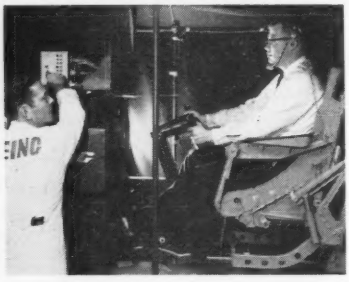
Hats off to Ronald G. Griffith, P.Eng of Montreal. He's the man in the picture watching his brain-child at work. Smaller than most typewriters, the Griffith teleprinter weighs only 35 pounds, occupies desk space of 12 x 17 in., and is only 10 in. high. The machine will transmit or receive 75 to 100 words per minute. Design incorporates a number of novel features. For instance, it can be used as a read-out device for electronic computers and similar machines, and it will back up during transmission in order to make corrections in transmitted telegraph copy. Originally planned for Canadian production (in fact, all tooling had been completed) the patent rights have now been sold to a U. S. company for world-wide marketing.

Students tour Carbide's new home



The five young men inspecting the refrigeration system are architectural students. They are part of a group of forty students and faculty members from the School of Architecture, University of Toronto, that recently toured the new Toronto head office of Union Carbide Canada Ltd. The 11-story building is an architectural showplace. It has a two-level substructure of reinforced concrete. Superstructure is said to have the longest clear-span, multi-story steel frame in the country. On the exterior projecting columns faced wi.h black granite, extend from the first floor to underside of roof. The curtain wall is constructed from floor to ceiling of double plate glass, framed in stainless steel. Between these windows are stainless steel spandrel panels.

Off on a flight into nowhere

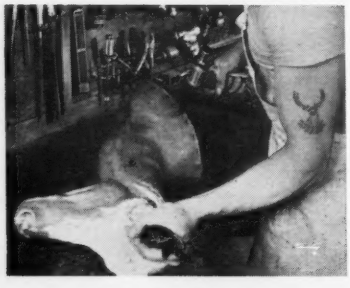


He feels like he's flying but he isn't. Nor will he in this cockpit. Boeing developed this flight simulator, integrated with their Electronic Analog Computer and equipment test mockup, to determine both dynamic and pilot reactions to critical manoeuvre conditions. Cockpit mockup includes standard control system and IFR flight ins:ruments, with oscilloscopic display showing horizon and runway for VFR flight simulation. Simulator is part of company's mechanical equipment laboratories at Wichita, Kansas. These laboratories have integral environmental test equipment, recording instrumentation, ranging from direct writing to complex multipoint automatic data systems, and a versatile analogue computing facility.

Raft of cases is a case of craft

Meet Mr and Mrs Huckleberry Finn and the three little Finns. As you can see they've found a way to beat both the heat and the high price of yachts. Raft consists of ten typewriter packing cases lashed to a wooden frame. Hardly the best construction for off-shore cruising but good enough for the local duck pond. Cases are made of foam polystyrene and are virtually unsinkable, hence the confident smiles. Makers of the typewriter, Royal McBee Corp., don't mind one little bit, in fact they offer the cases free at their sales offices. After all they're getting some pretty good advertising out of it. Fifty years from now these same kids will be saying "Yes, I always use these typewriters. Remember a case I used to float around on back in '60."

Now he's stalked and stapled, poor deer



Pity the noble deer that suffers this indignity. Tracked in the woods he now is tacked in the taxidermists. Jonas Bros., of Denver, the largest taxidermists in the world, we are told, switched from nails to staples in their operation and fastening speed, they say, has jumped 50 percent. For those interested in the process a clay model is first built up on a skeleton of wire and wood. From this a plaster cast is made and used as a mold for the final hollow form, called a manikin, that is made of laminated paper. It is to this final form that the cured skin is attached. At the Jonas plant staples are used throughout the process. The tattoo on the man's arm is not the badge of his trade. We gather it has something to do with the brand of cigarettes he smokes.

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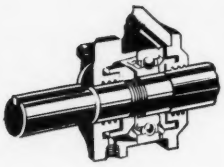
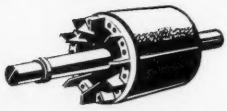


Transverse greasing cleans out old grease puts in fresh —longer bearing life!



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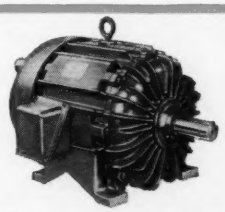
For standard motors heavy series S.K.F. ball bearings are used. Where extremely quiet operation is required, sleeve bearing construction is available.

In addition to these new CEMA frames 254U and 256U, 7½ and 10 h.p. ratings, Wagner also manufactures a complete range of h.p. and speed ratings in frames 56 to 256U. Ask your Wagner man . . . he knows!



Efficient cooling with ribbed frame and end bell in this CPJ, totally enclosed fan-cooled, and HPJ explosion proof (shown below).

Wagner ELECTRIC

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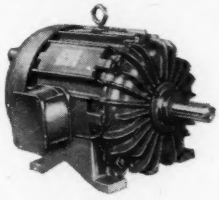
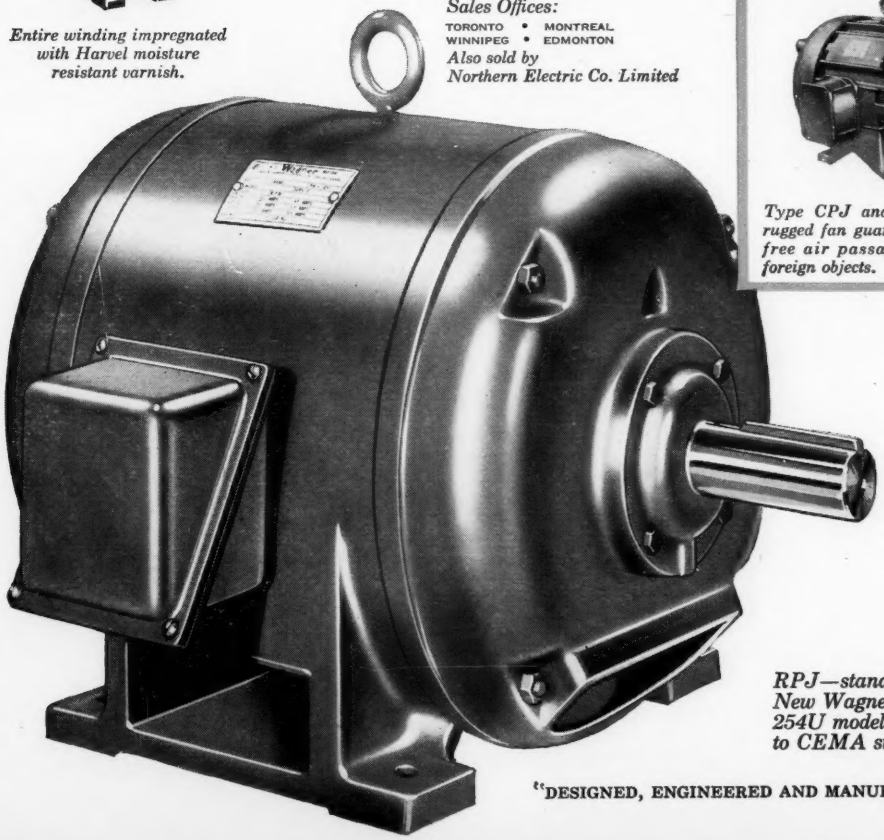


Type CPJ and HPJ have a rugged fan guard which allows free air passage—keeps out foreign objects.



RPJ—standard protected. New Wagner 256U and 254U models are built to CEMA standards.

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First in components for HYDRAULIC SYSTEMS

Look at anything . . . anywhere in the world . . . in hydraulics, diesel power or machine tool applications . . . equipment for instrumentation, oil drilling, mining, road building, petro-chemicals or even atomic power . . . chances are the vital air and fluid lifelines are secured with WEATHERHEAD.

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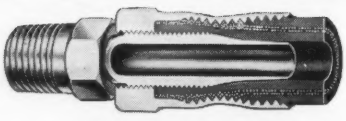
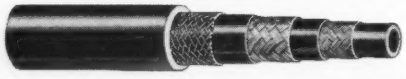
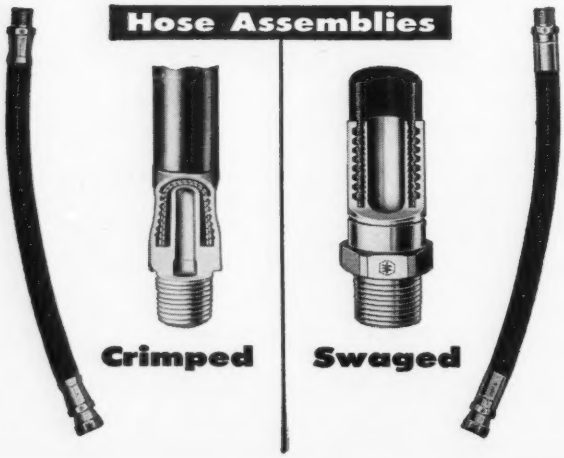


Bulk Hose



Hose Assemblies



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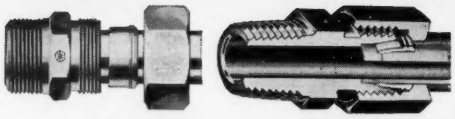
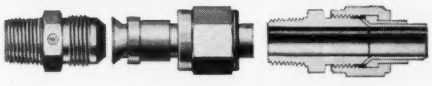


SAE 37° FLARE

3-PIECE

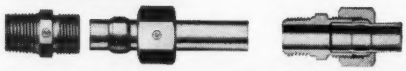


2-PIECE

SAE 45° FLARE

INVERTED FLARE

COMPRESSION



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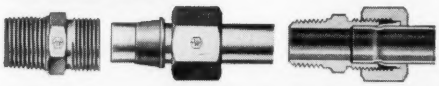
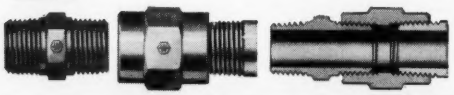
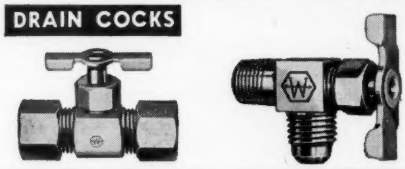


PIPE



DRAIN COCKS



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Designews

Nuclear Research in Manitoba

A site sixty miles from Winnipeg, Manitoba has been selected by Atomic Energy of Canada Limited for Canada's second nuclear research centre.

To be known as the Whiteshell Nuclear Research Establishment, the new centre will start as a small unit but will be expanded as nuclear research in Canada expands and may reach a size comparable to that of the Chalk River plant.

Shawinigan Engineering, Montreal has been appointed to do the over-all site planning and development.

We have just one question—any chance for changing this decision to read Elliot Lake, Ontario?

Bearing standards

The Technical Committee of The International Organization for Standardization met recently in Berlin to discuss Ball and Roller Bearings. Mr. B. L. Haley, vp engineering at the Canadian SKF Company, official Canadian delegate, reports that considerable progress was made in the standardizing of instrument bearings and tapered roller bearings. The work of this committee in rationalizing sizes and establishing interchangeability will have far reaching importance to users and makers of ball and roller bearings the world over.

Salt on highways

Use of salt on highways and streets during winter has become a serious matter of contention in Ontario. Although the subject is only on the fringe for designer interest, we thought you would appreciate the following.

During one snowstorm this winter, Rochester, New York used no salt, only snowplows. No one was advised of the experiment because the unbiased reactions of police officials, traffic engineers and the public was wanted.

The two officials who initiated the program reported that the office of snow control was flooded with complaints from the police, transit company and many private citizens. "The superintendent of street cleaning said conditions would become intolerable unless salt was used. And the remarks of individuals were acrid," says the report.

Finally, the order was given to salt the streets; the hazardous conditions were relieved after one run of the salt spreaders. An hour later the city was back to normal.

An interesting report indeed — with the challenge still beckoning the design engineer to develop a vehicle that will not fall apart (due to corrosion) long before its useful life would otherwise be ended.

IAPA Annual Conference

The Annual Conference of the Industrial Accident Prevention Association will be held at the Royal York Hotel, Toronto on the 4th and 5th of April 1960.

Safety is a major consideration in all designs — or rather, it should be — and the annual conference is an ideal place to get the latest facts and figures on this subject.

No IRE show this year

The next convention of the Institute of Radio Engineers will be held October 1961, the planning committee recently announced. Postponement for a year will pave the way for an expanded technical program and increased industry participation.

CSA Publications — 1960

The 1960 issue of CSA List of Publications has just been published. All currently available CSA Standards are listed here, according to subjects. In addition, publications of the International Organization for Standardization (ISO) and of the International Electrotechnical Commission (IEC), which are distributed in Canada through the Canadian Standards Association, are listed. Price is given with each title. Names and addresses of sales agents for CSA Standards in other countries are also included in this list which is distributed without charge by the CSA Headquarters in Ottawa.

Hot water supplies

Industrial hot water, spotted throughout the plant at points of use, is rapidly replacing the method of delivering hot water through long lines from a central heating boiler, it was stated during the 1960 Maintenance and Engineering Show.

Many plants are finding it more economical to use the new compact water heaters, with the hot water generated right at the exact location of need and in the required capacity.

Die-casting display in Toronto

The Die Casters' Section of the Automotive Parts Manufacturers' Association (Canada) is planning to hold a display of die castings, with an accompanying technical film and panel discussion, in Toronto in the latter part of May.

A number of similar functions have been held, particularly with professional groups, and it has been suggested that design engineers would welcome an opportunity to participate in a function of this nature. There would be a physical display of die castings and a discussion on how they are made, the complex forms which can be cast, the ingenuity and originality in design which is permitted through this method of metal working, and many other features which permit die casting to supplant other methods of production. The various applications of die casting would be shown, such as in the automotive industry, marine hardware, household appliances, and lighting fixtures.

The Canadian die casting industry is prepared to put on this function without charge for the benefit of design engineers, provided that sufficient interest is shown at an early date by response to this notice. Subscribers to this magazine who would be interested in the program are invited to write direct to the Secretary, Automotive Parts Manufacturers' Association (Canada) Suite 408, 77 York St., Toronto 1, Ont., giving their company affiliation and title. If you wish, circle number **371** on the Reader's Service card and DE will do the rest. Those interested will be notified of the time and place of the meeting. ***Will you be there?***

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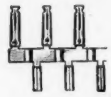

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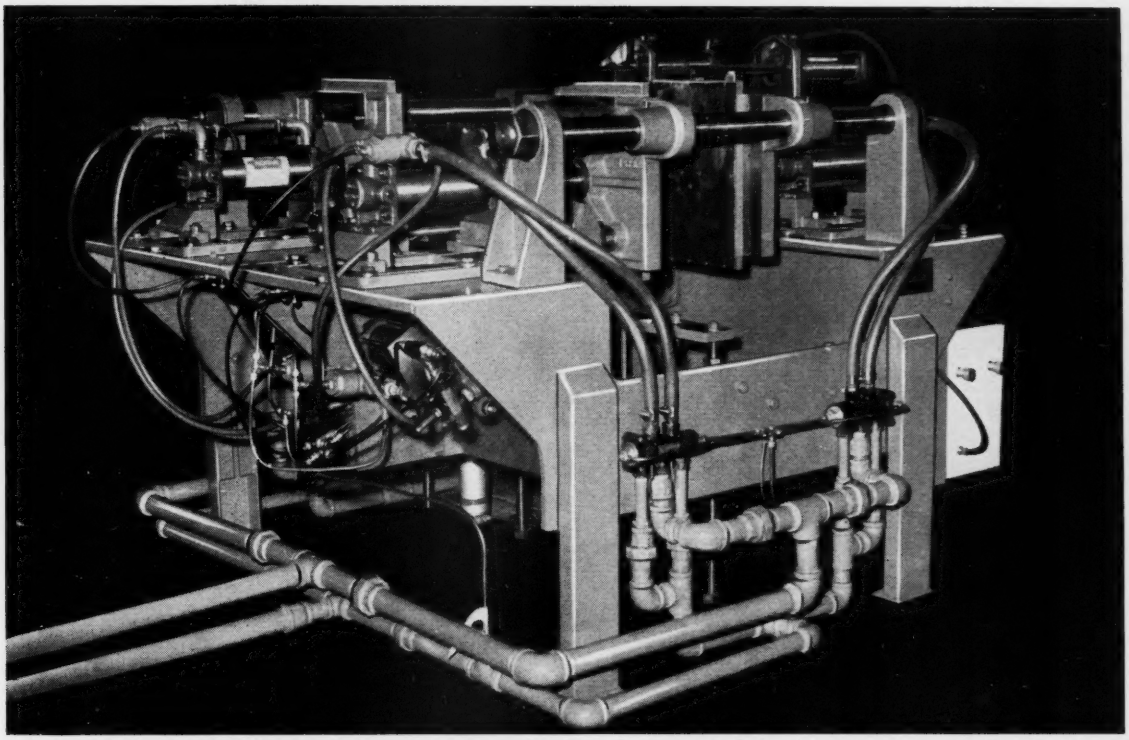

Maxam-Nopack pneumatic control guides this new Blow-Moulding Machine, built for Tayklo Holdings Ltd., by Delamere & Williams Ltd. of Toronto

Air power makes plastic containers on this machine. Starting with an extruded plastic tube that never stops, never changes its rate of flow, the machine automatically clamps on a mould, forms the plastic inside the mould with compressed air, cools and finally ejects the finished product.

The operation—using hydraulic pressure, compressed air and vacuum on a single circuit—demanded exact synchronization and complete reliability in its control system. The designer's choice—MAXAM-NOPAK air/hydraulic equipment!

This prototype was designed and built with the close co-operation of MAXAM-NOPAK's technical staff. The performance of the machine and the accuracy of its unique control circuit have warranted production of other units for the plastics market.

For full information on MAXAM-NOPAK equipment—and for pneumatic or hydraulic design assistance—write:

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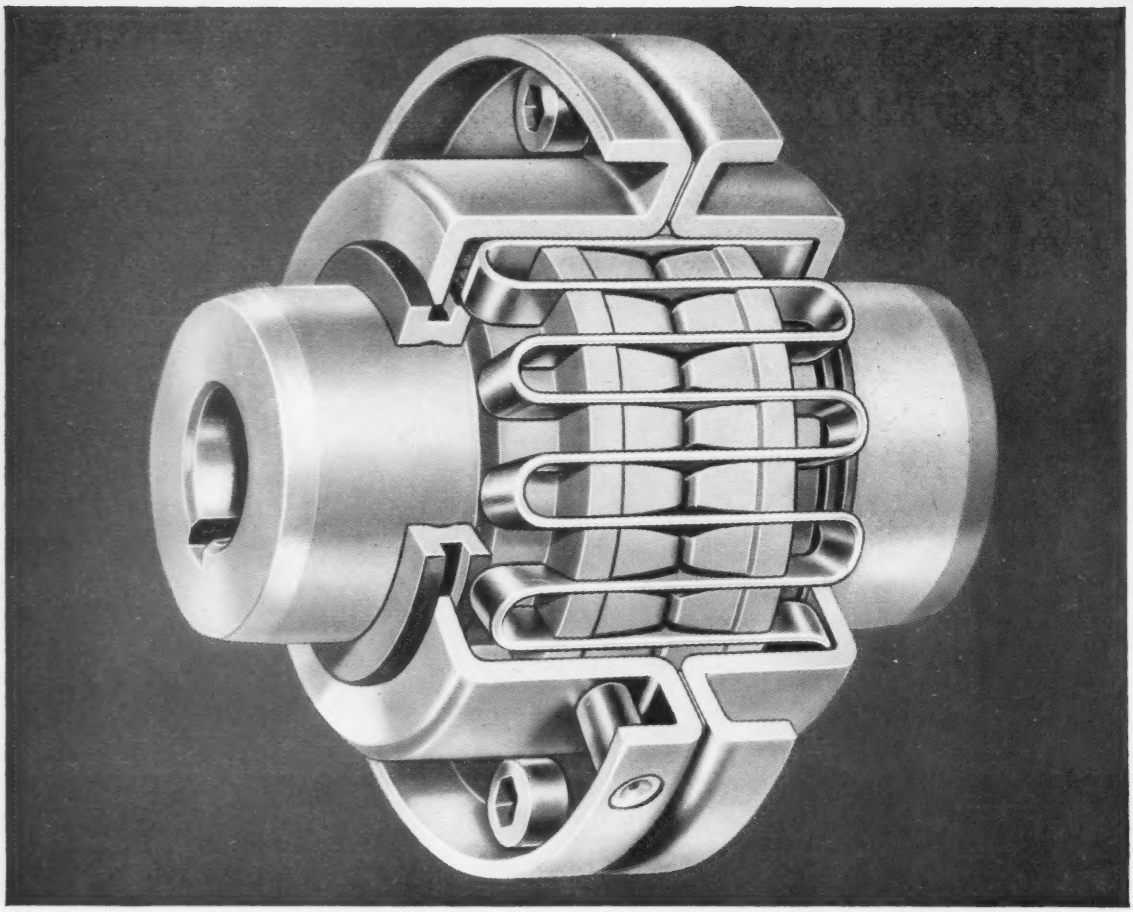

Falk distribution now complete

Famous Falk Couplings and Reducers at last in good cross-Canada supply

Canadian Allis-Chalmers is pleased to announce that FALK—America's "royal family" of couplings and speed reducers, are now manufactured in Canada, under license, by CA-C. FALK Steelflex Couplings are the overwhelming favourite of discriminating buyers in every industry because they have learned that the exclusive grid-groove design smothers shock and vibration as no other can. They accommodate parallel misalignment, angular misalignment or free end float better than any other coupling made. They are exceptionally long-lasting...easy to install...easy to disconnect. Contact your CA-C representative or distributor about FALK's distinguished line, and about your coupling problems, or write Canadian Allis-Chalmers, P.O. Box 37, Montreal.

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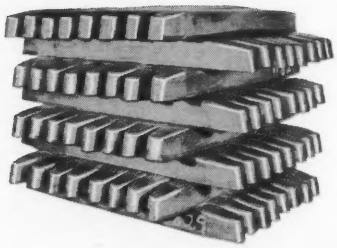
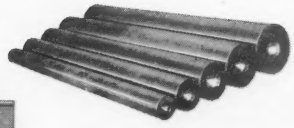
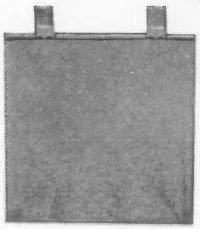
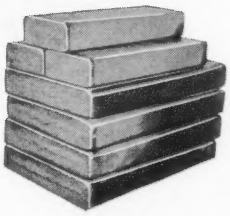
brand quality controlled copper









ORC Brand is the mark of quality stamped on all copper shapes produced by the Copper Refining Division of Inco. It signifies that the copper has been produced under carefully controlled conditions to attain high purity and safeguard quality throughout every stage of the complex refining process.

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ORC Brand Copper consistently exceeds the minimum copper content as specified in the trade standards. In fact metallic impurities are held below one part in ten thousand and the copper content of tough pitch electrolytic shapes, dictated by the presence of a regulated amount of oxygen, is generally in the range 99.950 to 99.970%. All wire bars, cakes, billets and related shapes have a resistivity not to exceed 0.15328 international ohm—gram/meter^2 at 20°C (annealed). All ingots and ingot bars have a resistivity not to exceed 0.15694 ohm.

Suppliers of:

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THE INTERNATIONAL NICKEL COMPANY OF CANADA, LIMITED

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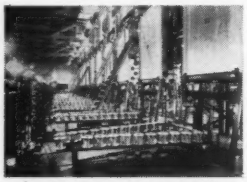
the new generation of MAGNET

Is there a better type of magnet wire for your job toda "Yes", has been the answer to many Canadian companie



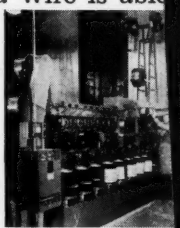
Production is completely automatic at the Canada Wire Magnet Wire plant at Simcoe.

Several factors, including miniaturization of equipment and the introduction of higher speed winding machines have resulted in a new generation of magnet wires.

Perhaps one of the new types (a few are described below) will suit your requirements much better than the one you are now using.

There is one sure way to find out. Tell us about your product and manufacturing process. Canada Wire makes all the latest types of magnet wire, so Canada Wire is l equipped to advise if there is now a be type of magnet wire for you.

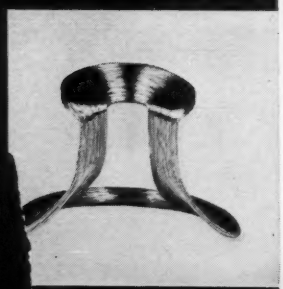
One reason why Canada Wire is able offer such specialized magnet wire service to industry is the modern research and manufacturing facilities centralized in the Magnet Wire Division plant at Simcoe, Ontario...the first Canadian plant devoted solely to the specialized job of producing the new generation of magnet wires for you.



Every type of modern packa is offered; Pail-Paks, Ba Paks and a complete rang spool sizes.

BONDEL

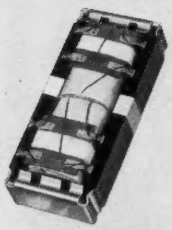
A Formel insulated wire with a thermoplastic cement overcoat. This overcoat softens when exposed to heat (275°F) or solvents (alcohol). Will bond the wires in a desired shape on cooling.



Deflection Yoke Coil for Television

NYLON

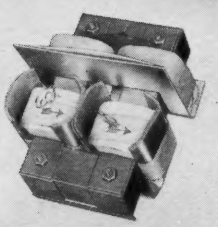
A polamide coating wire characterized by excellent windability and ability to solder in dip operations at temperatures of 650°F. to 750°F. without prior removal of coating.



Fluorescent Lamp Ballast Transformer Coil

PLAIN ENAMEL C-90

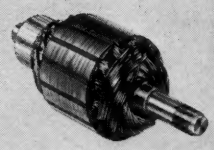
Insulated with an oil resin varnish film. Provides outstanding electrical properties in very thin film build-ups.



Oil Burner Ignition Coil

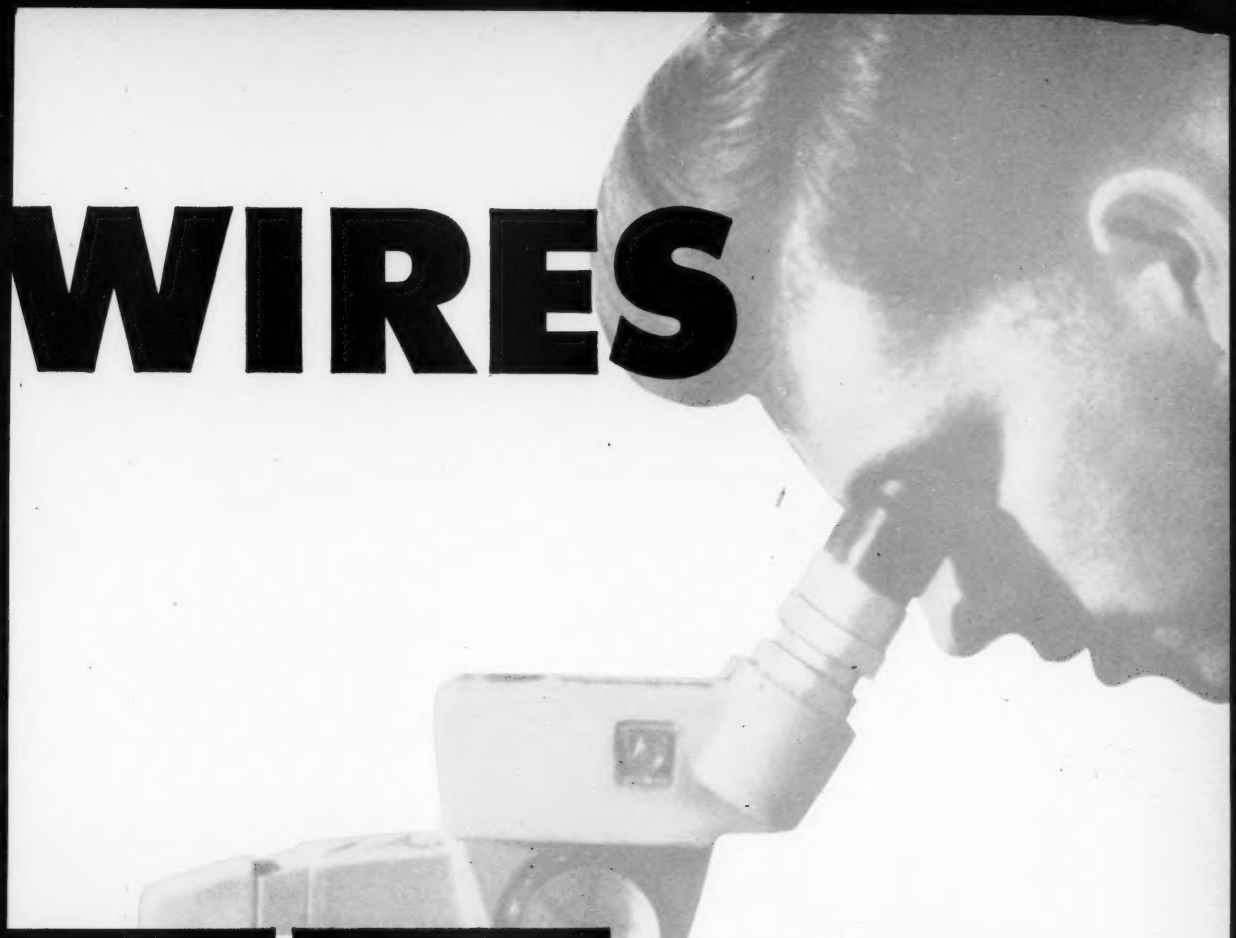
POLYSOL-N

Polysol insulated with a nylon overcoat. Combines the excellen windability and solvent resistance of nylon with the outstanding electrical characteristics of polysol. For soldering in dip operations without prior removal of coating.



Automotive Generator Armature

WIRES

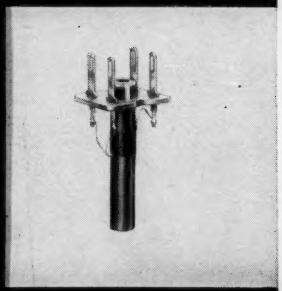


POLYSOL

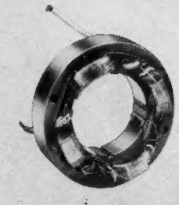
A modified isocyanate coated wire characterized by its excellent electrical properties (particularly at high frequencies) and its ability to solder in dip operations without prior removal of the insulation.

FORMEL

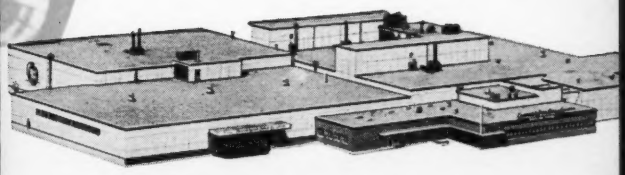
The best general purpose magnet wire now being manufactured. It is a vinyl acetal coated wire that has many outstanding properties for use in equipment functioning at temperatures not exceeding 105°C.



Electronic IF Transformer Coil



Fan Motor Stator Winding



Canada Wire's 113,000 square foot Magnet Wire Division plant was engineered from the ground up to manufacture one thing—magnet wire. Here, are the specialists and specialized equipment it takes to produce the new generation of magnet wires to the highest quality standards.

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Canada Wire and Cable Company Limited

Magnet Wire Division—Simcoe, Ontario

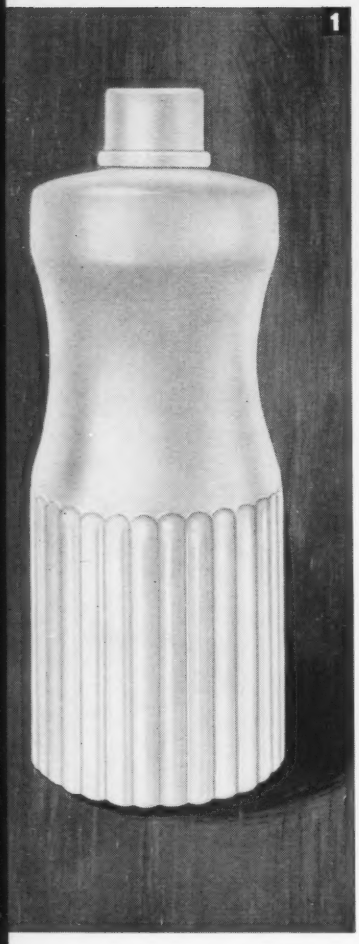
A *Canadian* Company Manufacturing and Selling Coast to Coast

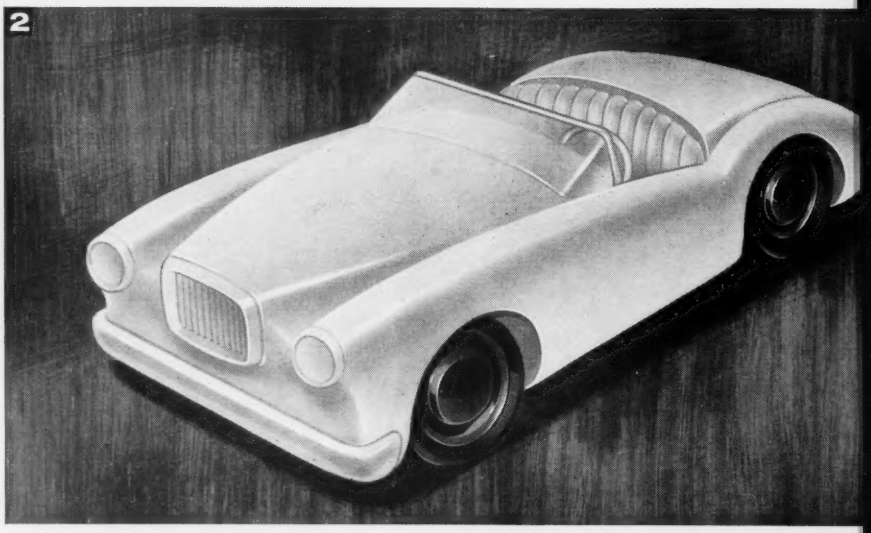
For further information mark No. 110 on Readers' Service Card

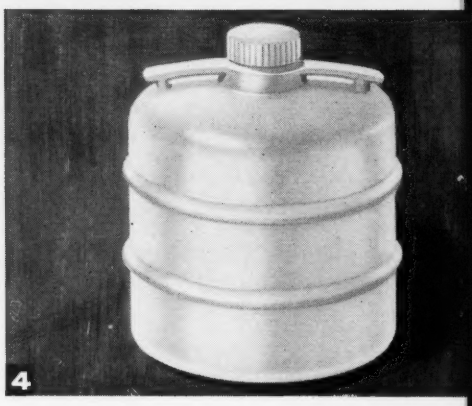
NEWS ABOUT

FORTILENE* AND BLOW MOULDING

Sometimes a material and a process make a natural team—as in the case of Fortilene and blow moulding. Together, they make it possible to re-design products for better quality and greater economy.







1 DETERGENT BOTTLES. Blow moulded of Fortilene, these attractive bottles are convenient to ship and handle, light in weight and virtually indestructible. Fortilene offers complete flexibility in design and moulded-in colours.

2 TOY CARS. Blow moulding is even invading the toy field. This model sports car illustrates the realistic detail possible. Fortilene gives it strength, durability and colour.

3 HOUSEHOLD VAPOURIZERS. Leading appliance manufacturers are discovering the advantages of Fortilene and blow moulding. Fortilene is inexpensive and simple to mould, available in attractive colours and withstands boiling temperatures.

4 CARBOYS FOR CHEMICALS. Fortilene and blow moulding could cause a minor revolution in the chemical products field. Fortilene containers won't rust, dent or leak, and are not affected by acids.

TO HELP YOU solve your plastics problems profitably, Canadian Chemical will be glad to send you literature and technical bulletins on Fortilene, and to supply on-the-spot assistance through their sales staff. Please call your Canadian Chemical office.

CANADIAN CHEMICAL COMPANY, LIMITED
Montreal • Toronto • Vancouver

*Reg'd Can. Trademark

Chemcell® PLASTICS

For further information mark No. 113 on Readers' Service Card

NOW – a rapid Design Consulting Service from CSF – at no cost to you!

In your production or purchases you may be using, or planning to use, parts which could be re-designed to your advantage—by reducing price, weight, or number of parts; or by increasing durability and strength.

A newly-developed Design Consulting Service by CSF will bring you a rapid and technically-accurate reply on how CSF can help you achieve any or all of these objectives.

To find out how this Service can work to your advantage, please fill in the Questionnaire below and mail to our Chief Design Engineer.

Tear along perforated line

DESIGN CONSULTING SERVICE
QUESTIONNAIRE

1. Service application of part.....
2. Loads or stresses, if applicable.....
3. Current or intended method of manufacture.....
4. Material specifications.....
5. Manufacturing tolerances.....
6. Finished weight of part.....
7. Finish required.....
8. What quantities of this part do you or would you normally fabricate or order?.....
9. Please attach drawing or sketch of part, along with assembly drawing.

Name of your Company.....

Address.....

Type of business or products.....

Name of individual making enquiry.....

Position within your Company.....

CANADIAN STEEL FOUNDRIES LIMITED

5227 Notre Dame Street East, Montreal 4, Que.

Member: A. V. Roe Canada Limited and The Hawker Siddeley Group

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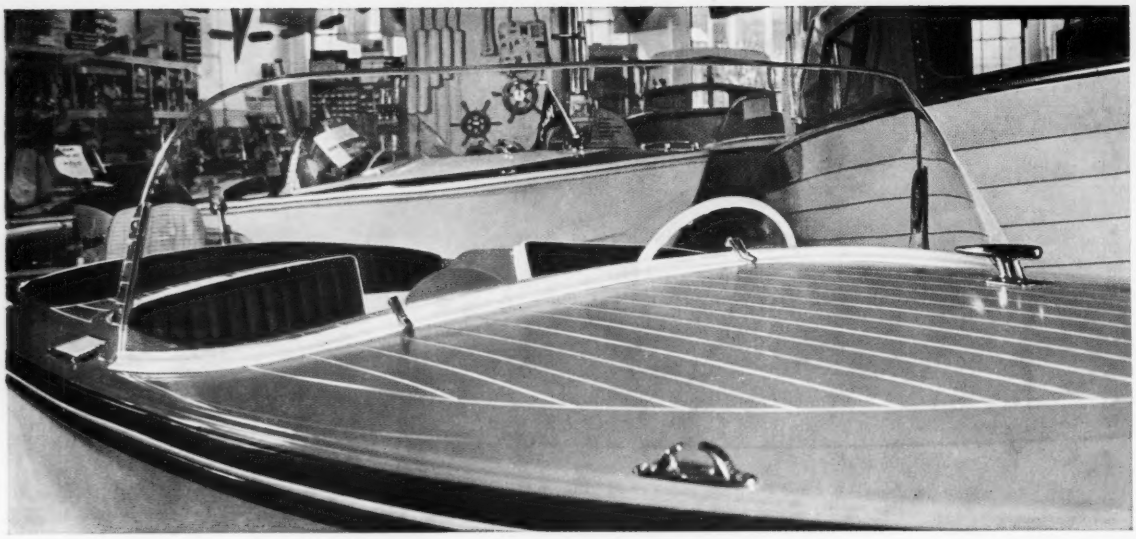

Handsome and Hardworking

Plexiglas ... Implex

Strong, gleaming, curved PLEXIGLAS® windshields on pleasure craft . . . rugged, colorful IMPLEX® housings for outboard motors (with molded PLEXIGLAS insignia) . . . both give merely a hint of the wide range of uses being made of these Rohm & Haas plastics. What do *you* have in mind? Signs . . . lenses . . . lighting diffusers . . . glazing . . . machine parts . . . housings . . . nameplates? Better look into PLEXIGLAS acrylic plastic or IMPLEX, the high-impact acrylic. Our design staff and technical representatives will be glad to tell you how these Rohm & Haas products can help you.

Chemicals for Industry

ROHM & HAAS COMPANY OF CANADA LIMITED

2 MANSE ROAD, WEST HILL, ONTARIO

PLEXIGLAS and IMPLEX are trademarks, Reg. Canadian Pat. Off. and in principal foreign countries.

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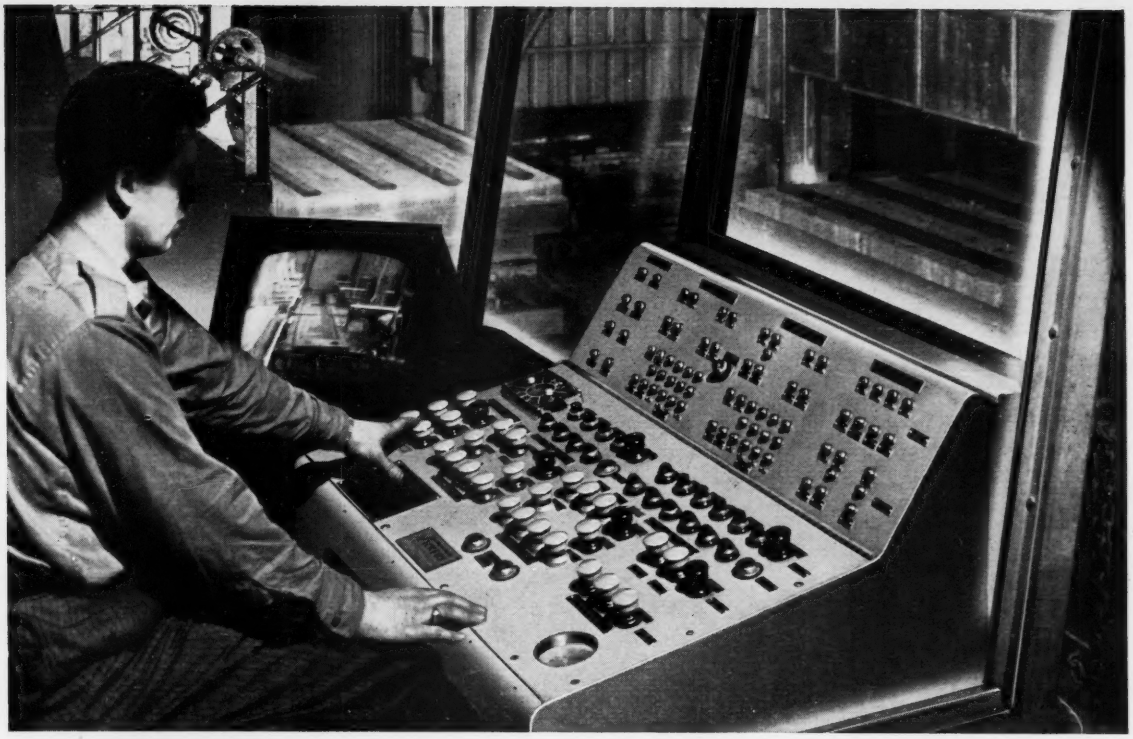
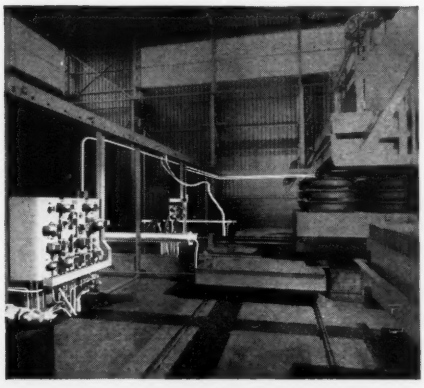


VICKERS® PACKAGED ELECTRO-HYDRAULIC SYSTEM

makes possible automatic heat treatment at Canadian Steel Wheel



Vickers control console at top of page gives operator remote control of normalizing furnace operations. Control console, power units, and valve panels like the one shown above are all part of the Vickers-Sperry package.

A combination of closed circuit TV and electro-hydraulic control permits a fully automatic heat treatment cycle for wrought steel wheels at Canadian Steel Wheel Limited's ultra-modern plant in Montreal. Depressing a selector button is all it takes to initiate a cycle. This new integrated plant can produce 200,000 wrought steel wheels per year to meet the increased needs of Canada's railways. This is accomplished by using the latest in automated manufacturing procedures and inspection techniques.

Vickers-Sperry of Canada Ltd. designed and manufactured the complete electrical and hydraulic control system for movement of wheels through the 90-foot long heat treatment furnaces. The complete "packaged" job included installation and startup of the equipment.

Although Vickers-Sperry "Packaged Systems" like this one are developed for specific installations, they use standard components throughout . . . thereby cutting original cost and simplifying maintenance because spare parts and service are readily available. You get not only single source convenience but *single source responsibility*.

A Vickers-Sperry application engineer can survey your requirements and show you how a packaged electro-hydraulic system offers the most efficient solution to your operating needs. Further information is available in Bulletin 59-74, write for your copy today.

VICKERS-SPERRY of Canada Ltd.

Division of Vickers Incorporated

SPERRY RAND CORPORATION

8463

VANCOUVER—1637 West 5th Ave. • TORONTO—92 Advance Rd. • MONTREAL—318 Victoria Ave.

VICKERS OFFERS WORLD-WIDE FACILITIES—SALES AND SERVICE

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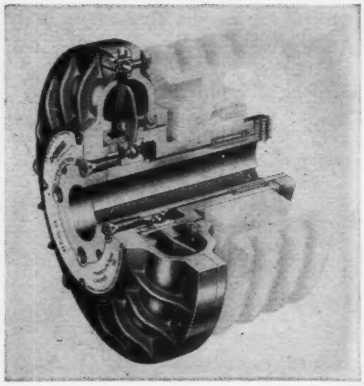
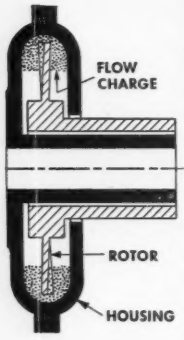
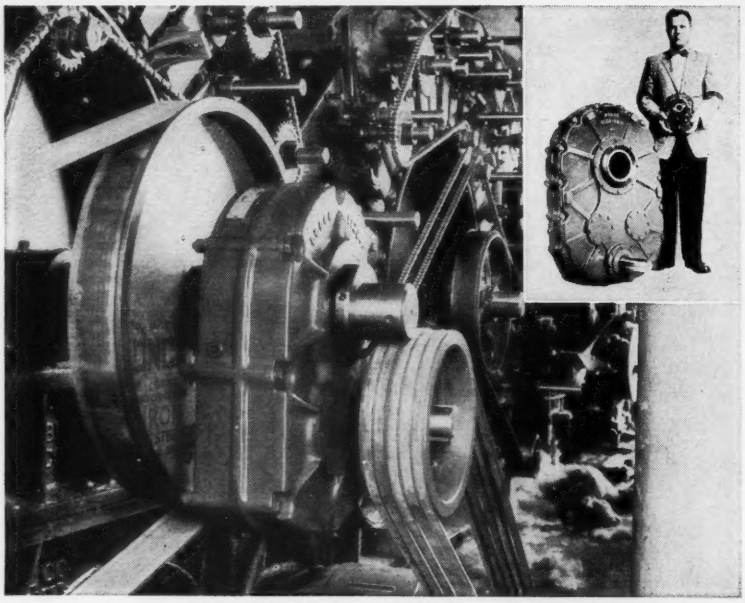
PRODUCT NEWS

FROM UNITED STEEL CORPORATION



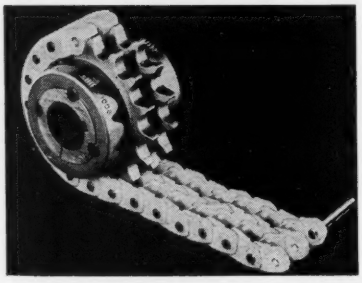
FLEXIDYNE "Dry Fluid" Drives and Couplings provide a new way to: start loads smoothly, protect against overloads; reduce maintenance; save on motors and controls. The "fluid" in Flexidyne is heat treated steel shot. A measured amount, called the flow charge, is contained in the housing, which is keyed to the motor shaft. When the motor is started centrifugal force throws the flow charge to the perimeter of the housing, packing it between the housing and the rotor which transmits power to the load. After the starting period of slippage between housing and rotor the two become locked together and achieve full load speed, operating without slip and with 100% efficiency. The Dodge Flexidyne Drive is available to handle from ¼ HP. to over 800 HP. **No. 6801.**





TORQUE-ARM SPEED REDUCERS— "Torque-Arm" is a precision built power package which simplifies problems of speed reduction and in so doing cuts the cost of equipment, installation and operation.

The reducer is mounted directly on the shaft to be driven thereby eliminating the need of costly linkage, foundation, sliding motor base or flexible coupling. Simple installation is effected by sliding the unit over the shaft and locking it in place with four screws. Combined with a V-Belt drive the Torque-Arm Speed Reducer can provide speed ratio up to 150-to-1 by selection of a predetermined combination of reducer and drive. Capacities up to 170 HP. with output speeds from 10 to 400 RPM. Overload Release and Backstop Mechanism, optional extras. **No. 6802.**



NYLON CHAIN COUPLING. Will outlast metal by as much as 6 to 1—costs less to buy and maintain. Specially suited for areas where corrosion is a problem. Ideal for loads fractional to 40 HP. and speeds 500 to 5,000 RPM. Used with standard ½" pitch roller chain sprockets. Quiet running; requires no lubrication or covering. **No. 6803.**

LIKE MORE FACTS? Simply check the item number and mail this coupon to: United Steel Corporation Limited, 58 Pelham Ave., Toronto 9.

☐ 6801 ☐ 6802 ☐ 6803

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TITLE.....

COMPANY.....

ADDRESS.....

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60-80

United Steel
CORPORATION LIMITED
TORONTO • MONTREAL • LONDON • GALT
WELLAND • KIRKLAND LAKE • SUDBURY

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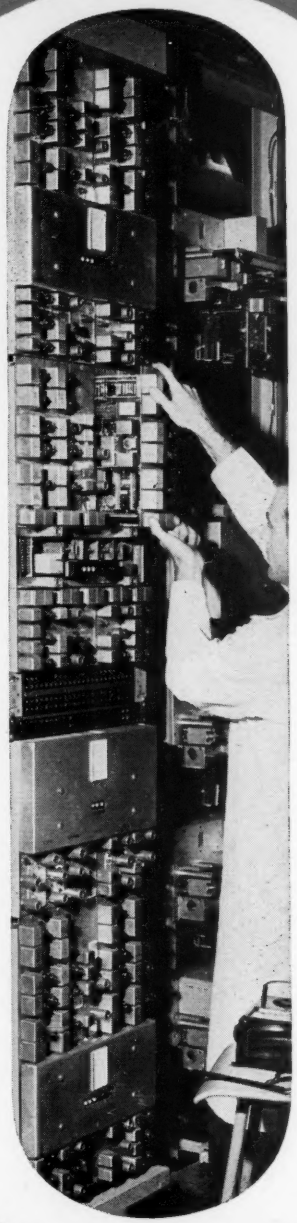

"OJ"

brings telephone communications up-to-date

Northern Electric research scientists have made another forward stride in the field of communications with the introduction of "OJ" — the latest and most modern carrier system and the first such system completely developed by this Company. The name "OJ" signifies that the system utilizes the modern techniques of the open wire "O" system and is compatible with the trans-continental "J" system. With the "OJ" system and with other great advances Northern Electric's skilled research and development team is setting the pace in the science of communications.

RESEARCH and DEVELOPMENT LABORATORIES

Northern Electric
COMPANY LIMITED

SERVES YOU BEST

6660-12

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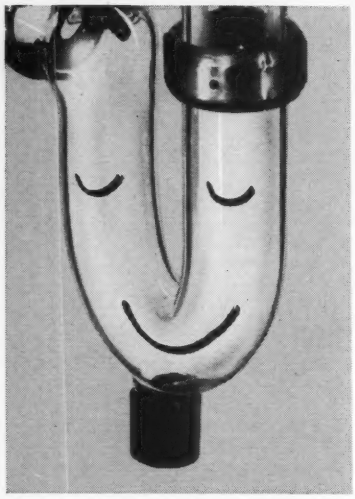
THIS IS GLASS

A BULLETIN OF PRACTICAL NEW IDEAS FROM CORNING

A GOOD OLD-FASHIONED GUARANTEE AGAINST DRAINLINE CORROSION



It's the sort of thing that drives stolid corporation lawyers to scribing frantic memos, *but* we are offering a hard-rock guarantee against corrosion and leakage with our PYREX® lifetime drainline.

We use "guarantee" in the old, unweaselworded sense of the term: we replace any piping material damaged due to corrosion and/or leakage *during the life of the building.*

We insert just one escape clause: we cannot tolerate, nor can the drainline, *massive* volumes of hydrofluoric acid, *hot* alkalies or *hot* phosphoric acid. Even here, check with us just to make sure. Anything else goes—acids, alkalies, or whathaveyou.

So throw away those drip buckets, stop giving the "new man" the desk under the leaking joint . . . the next time you install or replace a drainline, make sure it bears the "PYREX" trademark.

Look at the coupon.

Longevity under adverse, even hostile, conditions is a well-known trait of Corning glasses . . . a fact to consider, even ponder, when you run up against materials with but a modicum of stamina.

WHO WANTS TO TRANSMIT 80% to 90% OF INFRARED THROUGH A WINDOW AT 900°C. OR IN THE PRESENCE OF CORROSIVES?

Ours not to reason why. Ours only to inform you that there are two VYCOR® brand glasses that service both conditions admirably.

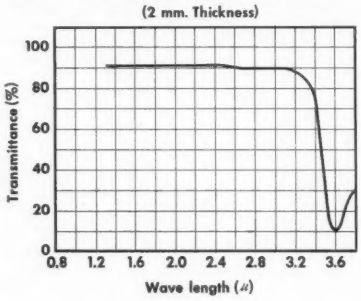
There is VYCOR No. 7905 glass. A sheet of this 2 mm. in thickness will transmit 90% of the wave lengths up to and including 3.0 microns. A ⅛ in. thickness will transmit 80% of a wave 2.75 microns across.

Then there is VYCOR No. 7950 glass. It is stained red. It does like work with infrared, but absorbs most of the visible light waves from a tungsten filament humming away at 2700°K.

Both glasses function continuously in the manners stated at 900°C. even in the presence of corrosives and will take intermittent jaunts into the 1200°C. plus region without damage.

Both will take a sudden thermal shock from these empyreal heights right down to 0°C.

INFRARED TRANSMISSION FOR GLASS NO. 7905
(2 mm. Thickness)

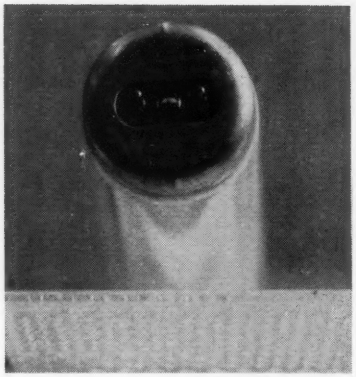


Both actually increase in mechanical strength as the temperature goes up. Odd, what?

There's much more you ought to know about these and the other VYCOR brand glasses, but we'd like to find out just how many and what kind of people are interested in such matters, so we've put the rest of the data away in a bulletin which you may have in exchange for the information asked for in the coupon.

silent light (fluorescent)

Making an electroencephalogram under fluorescent lights can be as nightmarish as listening to Leonard Bernstein conduct



in a subway. The same holds true for any sensitive electronic device that can pick up unwanted noise from a hot tube.

From now on, anyone seeing unworldly blips or blurs on his trace of a monkey's *alpha* waves might find our new PYREX brand E-C No. 70 panel helpful.

E-C No. 70 is a glass panel with an electroconductive coating fused to one side, a coating grounded with a ¼" strip of silver running around the perimeter of the panel. The coating is "tuned" to pick up and throw to the ground all radiation from 0.018 to 25 mc.

Add a simple line filter and a GBM ballast to your fixture, and all that comes out is clear, clean, quiet light, free from both radiated and conducted radio noise.

E-C No. 70 is optically designed to give low brightness to the light it lets through, this being 70 to 78% of the light emitted by the tubes.

E-C No. 70 is made of borosilicate glass, so it takes a goodly amount of corrosive atmosphere and thermal shock in stride.

E-C No. 70 meets all the many requirements of MIL-I-1690A—ships.

E-C No. 70 may be had in panels up to 28" in width, up to 48" in length.

Still more may be learned about E-C No. 70 by posting the coupon.

CORNING MEANS RESEARCH IN GLASS

CORNING GLASS WORKS, 39 Crystal St., Corning, N. Y.

Please send me: ☐ PE-30, PYREX lifetime drainline
☐ B-91, VYCOR Industrial Glassware
☐ A2, PYREX E-C No. 70 Glass Panels.

Name..... Title.....

Company.....

Street.....

City..... Zone..... Prov.....

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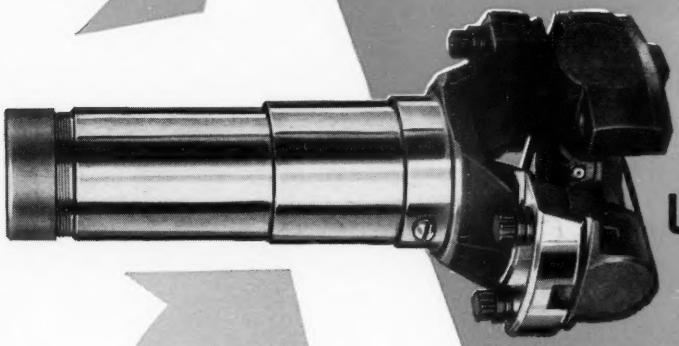
MORE MUSCLE IN A SMALLER PACKAGE... THE NEW

BLOOD BROTHERS "58WB" UNIVERSAL JOINT



To meet new drive line requirements on its 1960 model trucks, a major truck manufacturer needed a special, lightweight but strong universal joint—a unit that would provide greater torque capacity without increasing swing diameter. Rockwell-Standard engineers were consulted, and in a cooperative effort the new "58WB" was developed. It is now being used on several models in the manufacturer's 1960 line.

The design of the new "58WB" is applicable to medium-weight trucks, off-highway equipment, small crawlers and front-end loaders of approximately 1½ yards capacity. It can be made up as a complete drive line, furnished as a component part for a manufacturer's own drive line, or utilized in close-coupled drives. The "58WB" offers these outstanding advantages:

★ More capacity than any joint of comparable size. The "58WB" provides 39,000 inch pounds torque capacity with a swing diameter of only six inches!

★ Key-type yoke. Requires only four bolts for installation on original equipment. Saves downtime for repairs.

For more details about the new "58WB" or for help in solving any problems involving universal joints or drive lines, write or call us today.

Another Product of...

ROCKWELL-STANDARD
CORPORATION

ROCKWELL R STANDARD

Universal Joint Division, Allegan, Michigan

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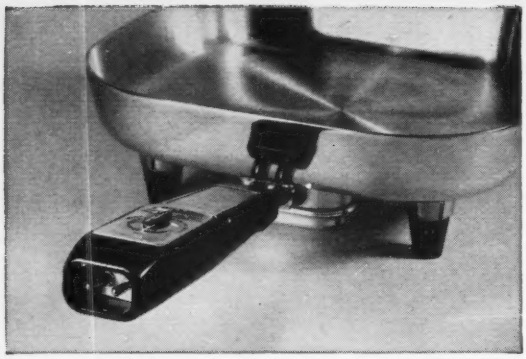
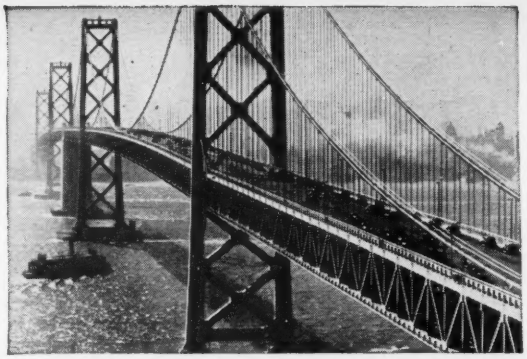


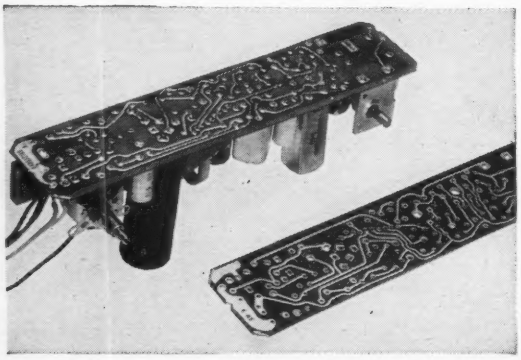
1 The handle of this automatic fry pan is molded of phenolic to:
(a) stay cool *(b) fit small hands*
(c) insulate inner wiring



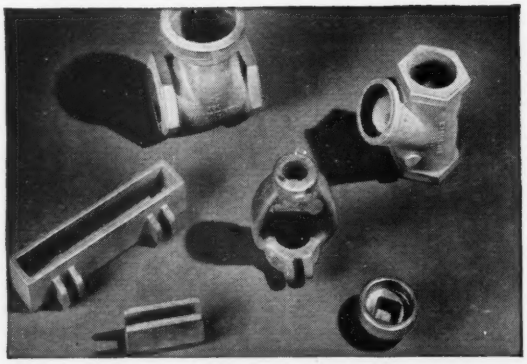
2 In 18 years, it's been re-coated with phenolic paints:
(a) 2 times *(b) 5 times*
(c) 9 times

Can you pass this test on Phenolic Plastics?

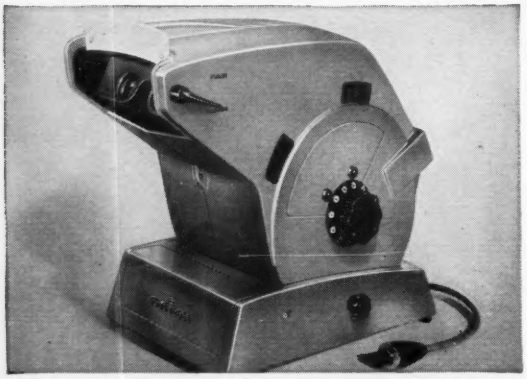
(You'll profit by knowing them better)



3 This modern electronic circuit is *printed* on a base of:
(a) molded phenolic *(b) phenolic-impregnated paper laminate*
(c) phenolic-coated metal



4 These smoother-finished metal castings result from:
(a) phenolic-bonded shell molds *(b) phenolic-based coatings*
(c) phenolic-bonded grinding wheels



5 This device to test vision has a molded phenolic case that:
(a) cuts weight 50% *(b) needs 25% less tooling*
(c) requires no coating

ANSWERS... *to design and production problems throughout industry are found in dependable BAKELITE phenolic plastics.*

1. Check (a) and (c), and add durability.
2. (a) Twice—phenolic paints last 7 years on the San Francisco Bay Bridge.
3. (b) A laminate—machineable, chemically inert, and non-conductive.
4. (a) Lightweight shell molds that virtually eliminate machining.
5. Check (a), (b), and (c)—it saved all around.

If you have questions—about phenolics and their potential for your business—please ask us. Why not discuss the matter with a Bakelite Technical Representative? Just write or call any of our offices, or write Bakelite Company, Division of Union Carbide Canada Limited, 40 St. Clair Ave. East, Toronto 7.

UNION CARBIDE

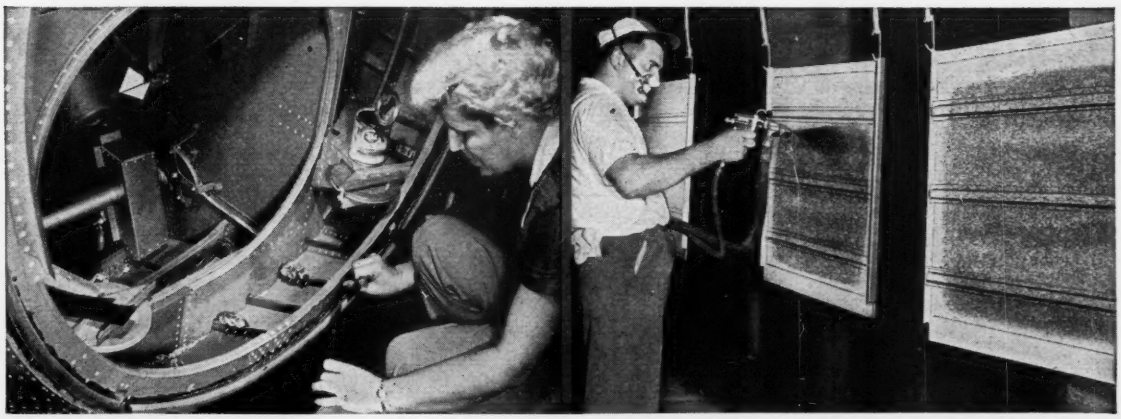
BAKELITE and UNION CARBIDE are trade marks.

For further information mark No. 105 on Readers' Service Card

BUILD IN STRENGTH, DURABILITY AT LOWER COST with 3M Adhesives, Coatings and Sealers

ROLL-ON SEALER. You just roll on 3M Brand Sealer EC-1202, apply the next metal section, then, fasten mechanically through the sealer. It's fabric-reinforced, neither shrinks nor stretches. With minimum labour and equipment, you get a durable, uniform seal that shuts out weather, dust and moisture.

COLD SANDWICH BONDING. 3M Brand adhesive EC-1357 makes it possible for you to bond sandwich panels with a nip roller or cold press. You need no clamps or heated presses to complete tough core-to-skin bonds that resist moisture and high and low temperatures. This one adhesive bonds a variety of sandwich materials quickly and economically.



RESISTS PLASTICIZERS. Sure bonding of nitrile rubber and vinyl plastics to metal is possible with 3M Brand Adhesive EC-847. This fast-drying, high-strength adhesive has exceptional resistance to many types of aggressive plasticizers, oils and fuels. Because of excellent adhesion to steel, aluminum, wood and leather, it serves countless uses.

DAMPS VIBRATION. One pass with a spray gun is all it takes to damp vibration of these movable wall partitions with 3M Brand Coating EC-1034. Heavy-bodied EC-1034 provides an easy answer wherever sound, air or machinery movement makes metal hum or rattle. What's more, it's moisture-proof, abrasion-resistant . . . protects metal and insulation.

SEE WHAT 3M ADHESIVES CAN DO FOR YOU! These are but four examples of ways 3M Adhesive Research is helping industry improve products and cut production time and cost. Look to 3M for the broadest range of adhesives, coatings and sealers experience.

MINNESOTA MINING AND MANUFACTURING OF CANADA LIMITED • LONDON, CANADA

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Sales Offices: Halifax • Montreal • Toronto • Winnipeg • Calgary • Vancouver
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Box 757, London, Ontario.

Gentlemen: Please supply further information on your products:

☐ EC-1202 ☐ EC-1357 ☐ EC-847 ☐ EC-1034

Please have a representative call regarding other products ☐

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COMPANY.....

ADDRESS.....

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003305

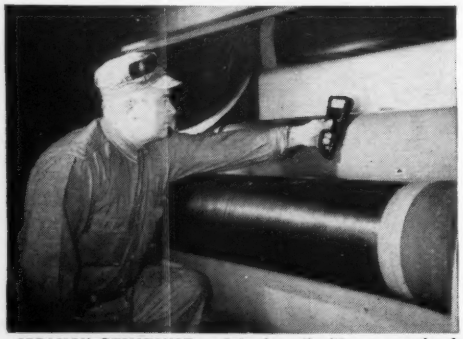
For further information mark No. 137 on Readers' Service Card

New Synthetic Rubber — "Hypalon" Helps Make Colorful Products that Perform Better.

CHEMICAL RESISTANCE — Hose with tube of "Hypalon" carries sulphuric acid and shows no internal damage in over two years of service. "Hypalon" resists strong oxidizing chemicals.

COLORABILITY — Auto door strips with coating of "Hypalon" in wide range of light, stable, matching colors are protected against ozone, sunlight and weather.

OZONE RESISTANCE — "Hypalon's" resistance to ozone is amazing! Compounds have been unaffected by the highest ozone concentrations producible in commercial generations.



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"Hypalon" is a relatively new Du Pont synthetic rubber. Its outstanding properties actually put it in a class by itself. "Hypalon" has extraordinary resistance to oxidation by sunlight and weather. It is completely ozone-proof. It resists heat and oxidizing chemicals.

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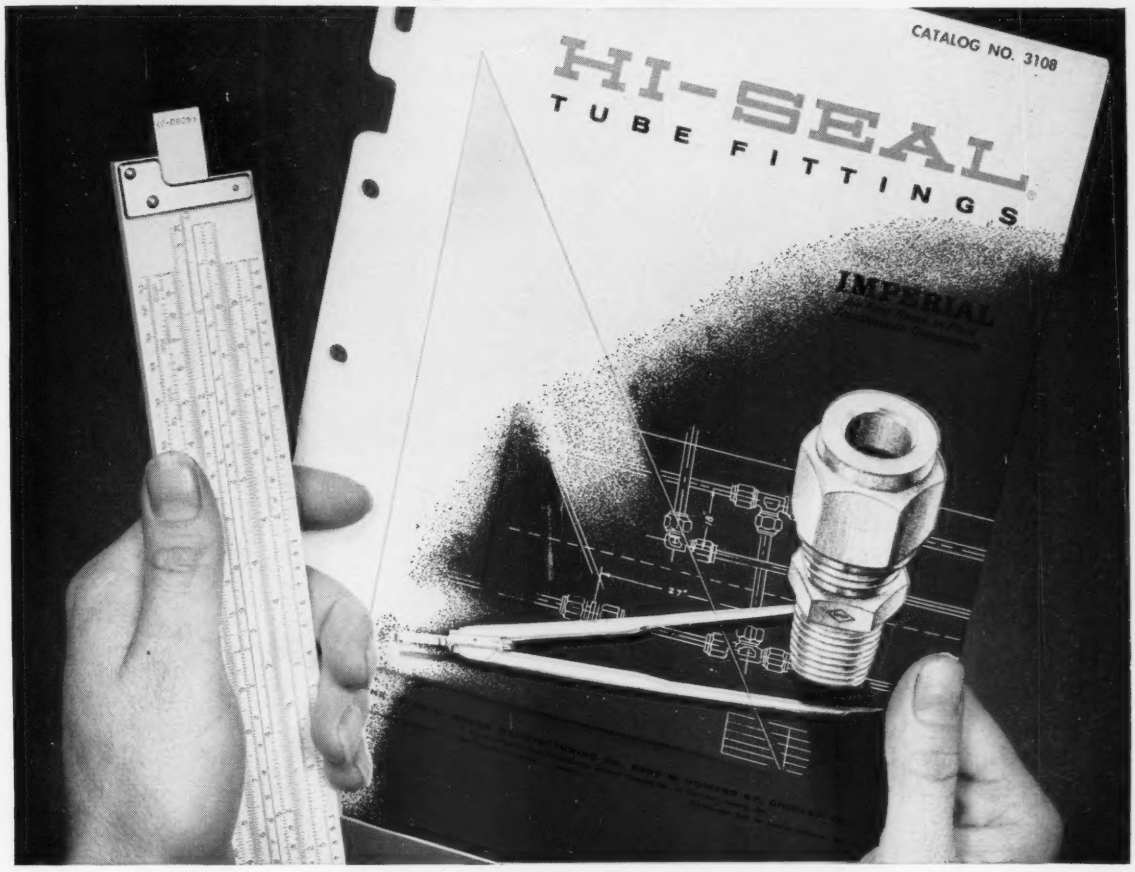

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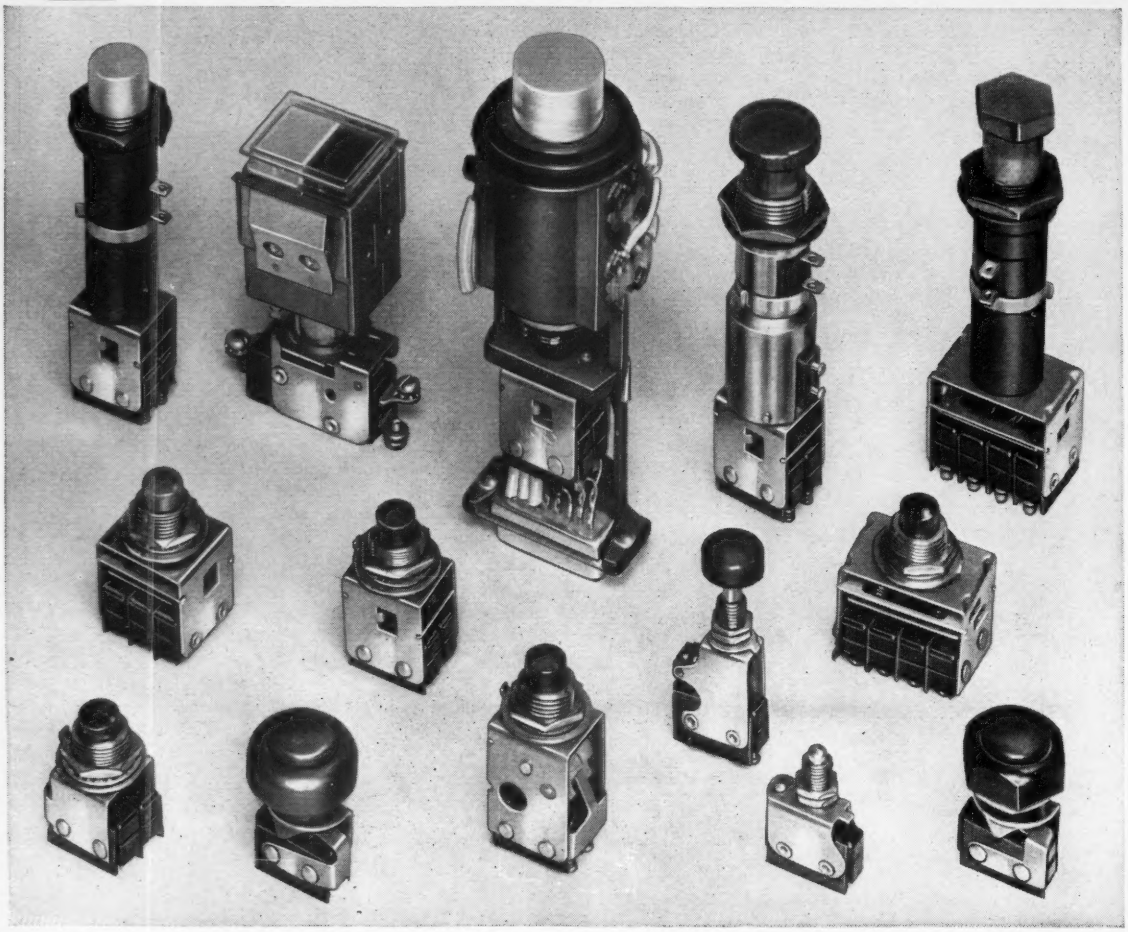

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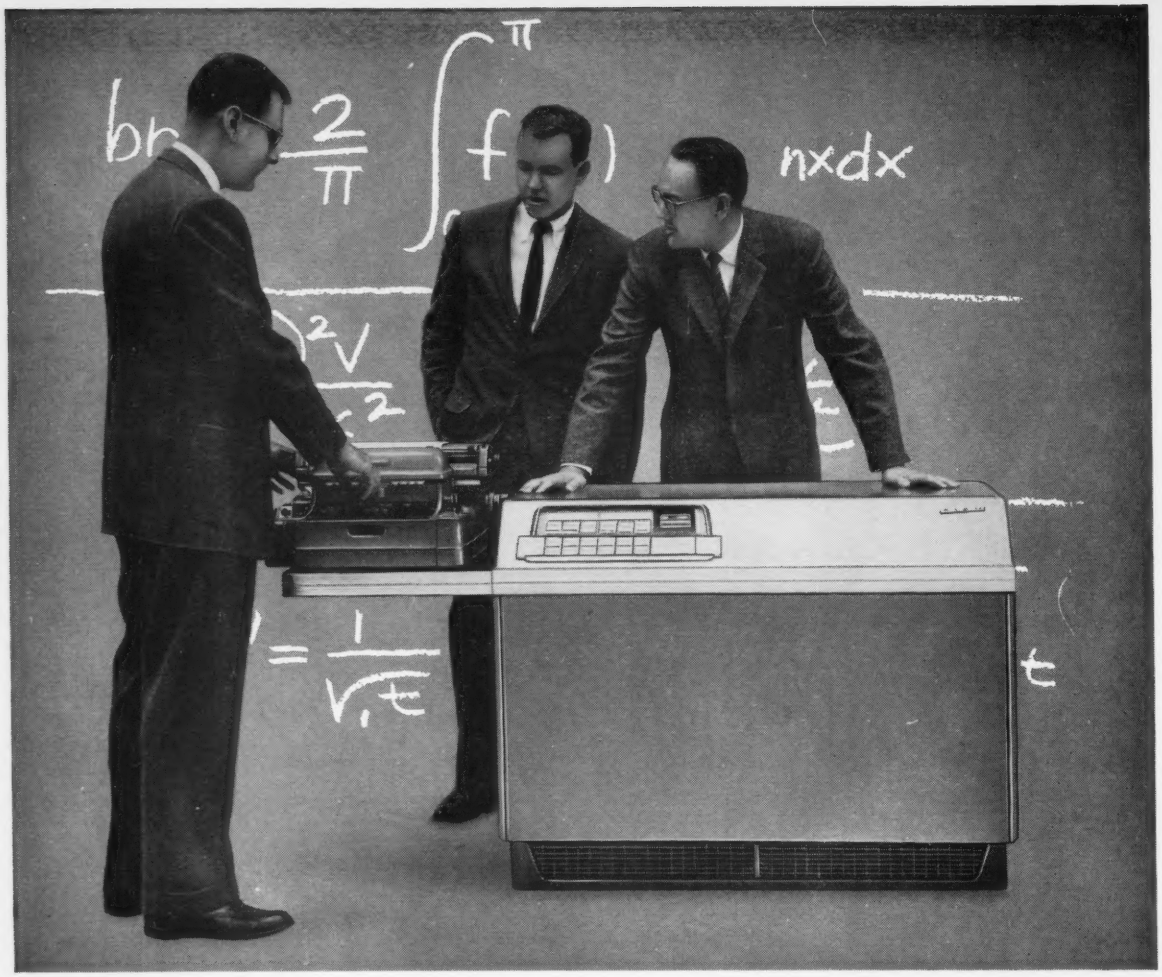

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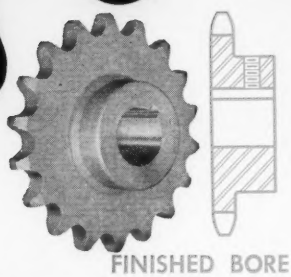

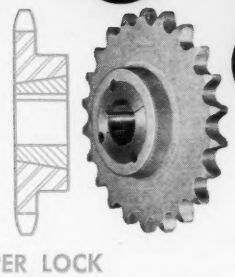

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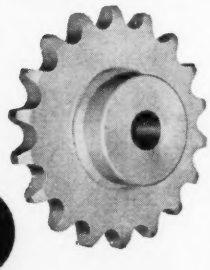
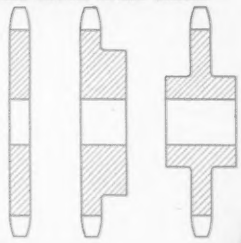
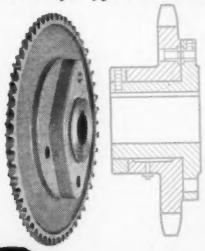


Mandrel bore sprockets are available in an extensive range of sizes for single- and multiple-strand roller chains. These sprockets are stocked with mandrel bores for remachining to individual bore or keyseat requirements. Type A (sometimes called plate sprockets) have no hubs and are used for mounting on flanges, hubs or other devices. Type B have a hub on one side only. Type C have hubs on both sides.





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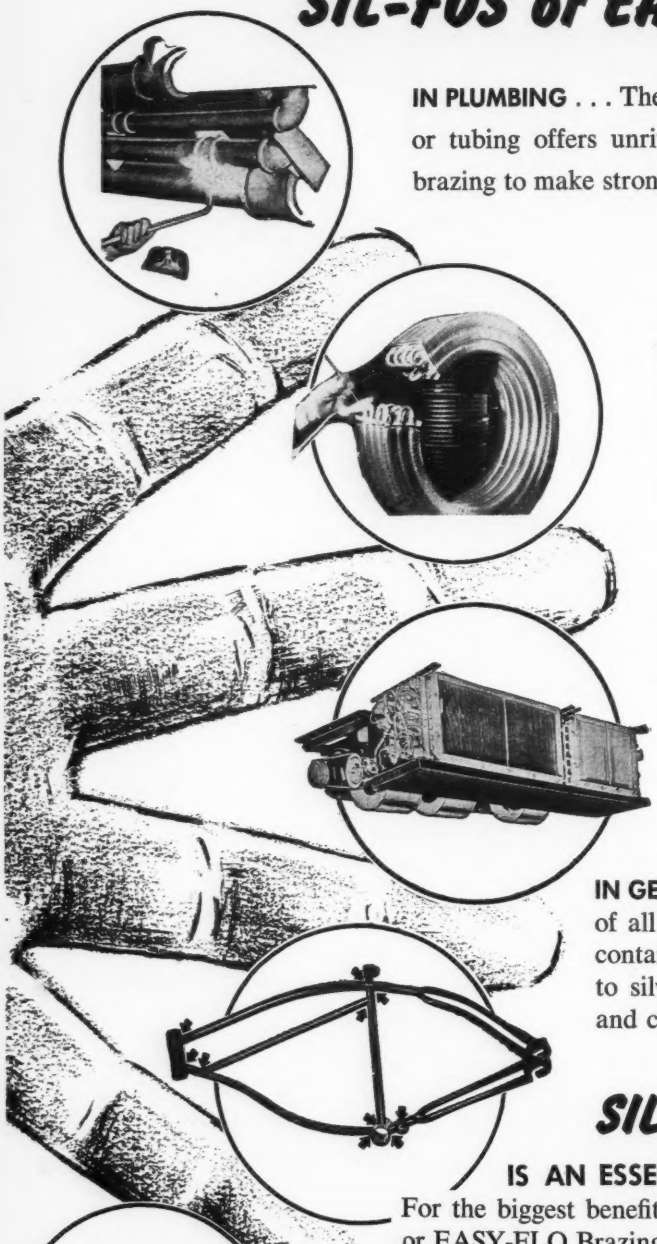

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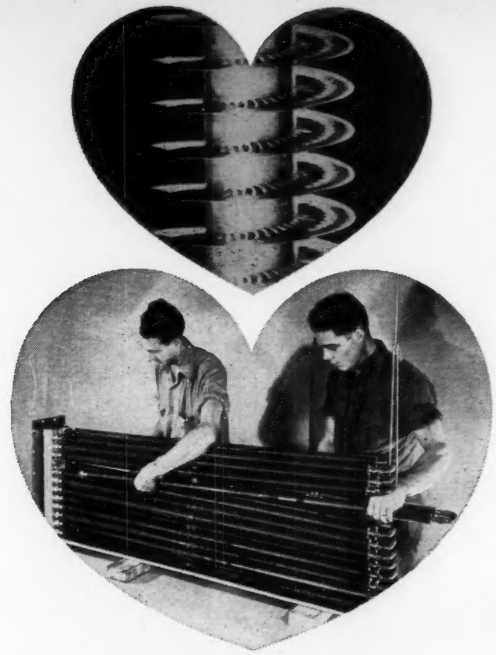

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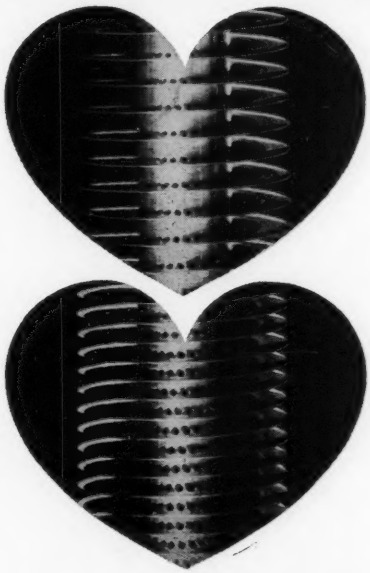

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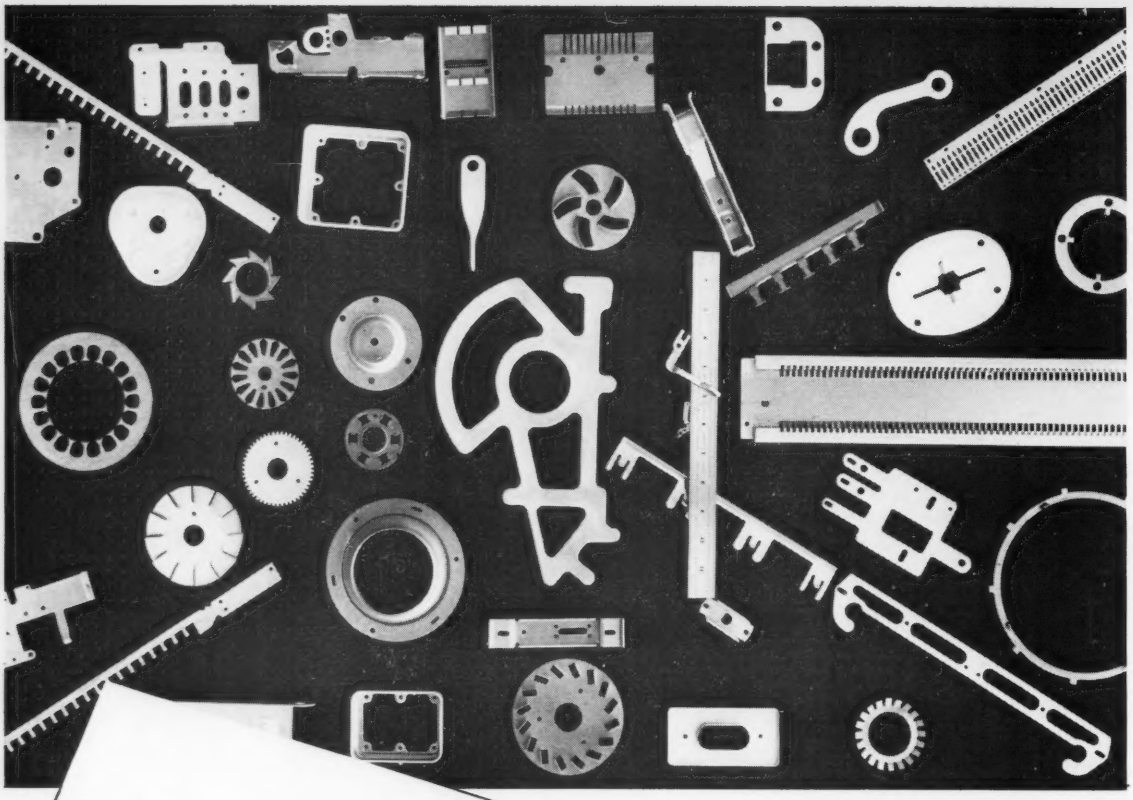

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Exclusive DE Feature

Workability— the secret of copper success

From primitive time to today's design engineer— the success story of copper

J. M. Scully

Workability—the ability of being worked has been the key to the use of copper and copper alloys from primitive man to today's modern design engineer.

The properties and working characteristics of the various forms of copper and copper alloys depend to a large extent upon such highly variable factors as size, shape and temper. For this reason the properties listed in the accompanying tables must be considered in general terms as they are approximate or typical values and should be used only as a guide. For specification purposes the design engineer should refer to the copper and copper alloy specifications published by the American Society for Testing Materials. Specifications for Canadian industry are currently being prepared by the Canadian Standards Association.

Copper base alloys are manufactured alloys. Brass is made by melting copper with zinc in varying proportions. The resultant "brass" is stronger than either of the original metals. Brass properties depend largely upon whether it is cast, rolled, extruded, drawn or annealed and upon the reduction by cold working following the last anneal. Machinability, corrosion resistance, hot and cold workability are controlled by varying the proportions of the basic metals and by adding small quantities of other elements.

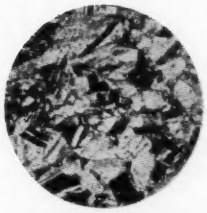
Mr. Scully, author of this article, is staff metallurgist with Noranda Copper and Brass, Limited, Montreal.

Microstructures of 70-30 Brass (magnified 75x)

Annealed

1 B & S numbers hard

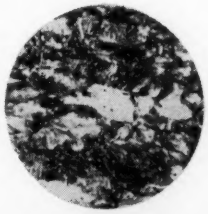
Quarter hard—11% reduction or 1B&S number hard. Metal cold rolled to this temper suited for shallow forming and severe bending.



2 B & S numbers hard

4 B & S numbers hard

Half hard—21% reduction or 2B&S. Suitable for general bending. **Full hard**—50% reduction or 4B&S. Suitable blanking, shearing, machining.



6 B & S numbers hard

8 B & S numbers hard

Extra and spring-extra hard—50% to over 60% reduction. Suitable for blanking, shearing, machining and bends if liberal radii.

continued ▶

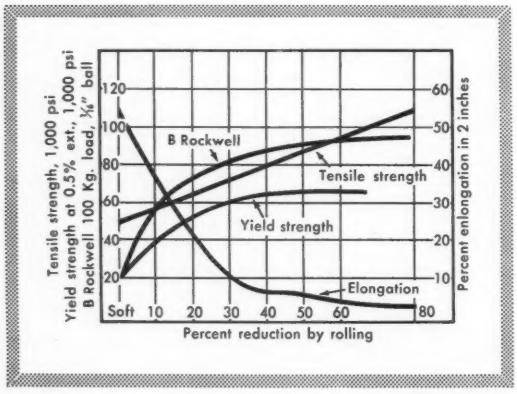
Workability of copper *continued*

Bronze was originally an alloy of copper and tin. However with modern usage bronzes now more properly could be defined as copper alloys for engineering uses having superior properties for specific applications. It is now general practice to qualify with an adjective descriptive of the particular alloy—we have for instance tin bronze, silicon bronze, aluminum bronze, etc.

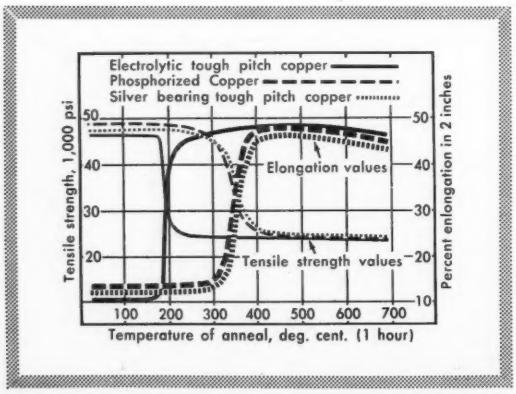
It is impractical to list the entire sequences that copper passes through from mine to consumer. This article deals only with those mill products that are developed from the new raw material after it is processed at the mill. When the ingot is melted and cast into bars and billets, alloys are made by adding other elements during melting. The bars are processed into sheet and strip, the billets are processed into rod, wire and tube.

General properties of copper and copper alloys

Few other metals, if any, contain as many desirable properties as copper and its alloys. Most of the common elements can be alloyed with copper to produce a tremendous range of properties, and these properties can be further refined by various methods of processing.



2. Tensile strength vs. percent reduction by rolling.



3. Annealing copper alloys—note inverse relationships.

There are approximately 100 alloys commercially available. In addition the mills will also, when the need requires, produce other alloys on a "made to order" basis to meet exact specifications required by a fabricator. The following properties are found or developed in copper and copper alloys.

1. Ease of workability
2. Exceptional corrosion resistance
3. Good strength
4. Excellent machinability
5. High electrical conductivity
6. Fine spring properties
7. Ease of finishing
8. Wide color range
9. Superior properties at sub-normal temperatures
10. Resistance to fatigue.
11. Nonmagnetic properties
12. High thermal conductivity.

We intend to deal specifically with the first named property. **Ease of workability.** Copper base alloys are readily drawn, formed, stamped, spun, cold and hot-forged, machined, etc., with a minimum effort, with least wear on tools and with recognized economy.

Effect of cold working

Hardness, strength and spring properties of wrought copper and copper alloys correspond to the amount of cold working which the metal receives after the last anneal. Also, ductility is adversely affected by the degree of cold working.

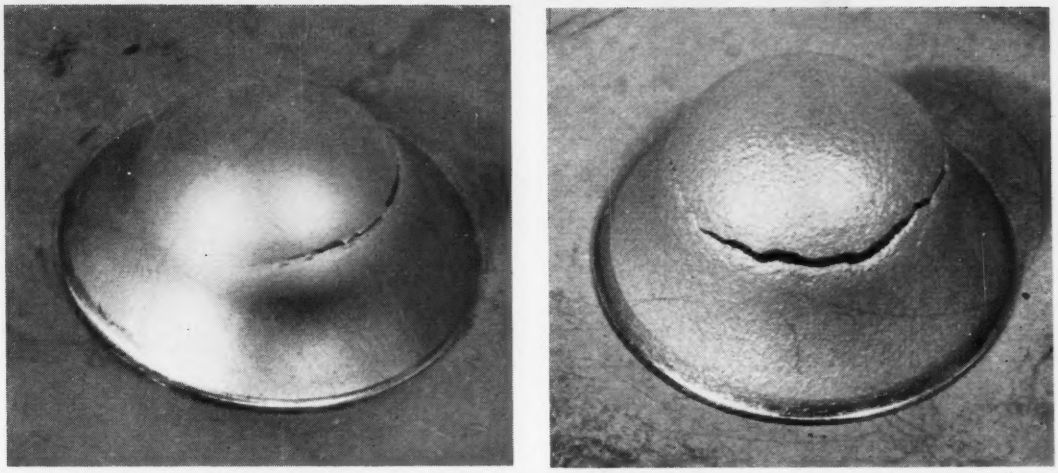
The comparison of the effect of cold working various brass alloys can be illustrated from the attached photomicrograph and accompanying graph (figs. 1 & 2). The grains are elongated in the direction of rolling, the tensile strength of the annealed material, formerly about 48,000 psi, rises to approximately 111,000 psi after a reduction in metal thickness of about 80%. The Rockwell hardness curve rises rapidly up to a reduction of 50% but flattens out with further cold working. Also the percent elongation value (ductility) drops rapidly as the metal hardens. Other brass alloys are similarly affected by cold working.

Note that the stronger alloys, those higher in zinc, lower in copper, harden and strengthen and lose their ductility more rapidly with cold working than the higher copper, low zinc alloys.

Cold working involving press work

For press operations, involving cupping and drawing copper, brass and most copper base alloys are supplied in the soft or annealed condition. Copper has high ductility but also low tenacity and a low rate of work hardening, which in some cases is found detrimental. It will take severe deformation, particularly deformation in one operation, before reannealing. However, unless process anneals are used, breakage will be encountered on certain types of draws requiring high tensile properties in shell walls and involving severe diameter reductions as well as wall reductions. The relatively soft bottoms in copper shells do not withstand well the loads involved in severe reductions of diameter. For these particular severe jobs special coppers such as de-oxidized copper can be used.

When drawing yellow brass (70-30 or 65-35) with its higher strength it is possible to obtain substantial diameter reductions as well as wall reductions before reannealing is found necessary. Brass jobs are usually laid out with about a 45% reduction of area from blank



4. Comparison of proper and improper annealing. Cup on right was drawn from copper which had been over-annealed. Note the rough orange peel type surface, which will require costly buffing and polishing operations.

to cup and with about 30% redraw reductions between anneals.

The harder, more refractory copper-base alloys such as the phosphor and silicon bronzes are also readily drawn, but require slightly more attention than with copper or brass.

Spinning

Although copper is generally considered to be one of the easiest metals to spin, soft tempered, brass, bronzes and the nickel silvers are also used extensively in industrial spinning. Tempers on all these alloys are well on the soft side, in the case of brass running around 0.045 min. average grain size. Copper is ductile enough to take severe spinning without annealing. However, for intricate shapes the other copper alloys workharden faster and may require annealing.

Cold heading and extrusion

The non-leaded high brasses are especially suitable for cold heading operations and they generally can be upset about three diameters. Tempers of yellow brass wire for heading will vary from 7 to 40% hard as supplied, depending on the severity of heading operation and the shape or design of the bolt, screw or rivet.

Low brasses (80% copper, 20% zinc) can be upset more than three diameters as can be the 2% type B silicon bronze (Cu98% Si 2%). The silicon bronze because of its great ductility is successfully headed on stock with a 90,000 psi tensile. Leaded brasses containing less than 2% lead are limited to 2½ diameters and those containing more than 2% lead to 1½ diameters as is the case with naval brass (Cu 60%, Sn 0.65%, Zn balance).

Annealing in fabrication

In the process of deep drawing shells or similar items in stages, it is often necessary for the fabricator to anneal or soften the previously cold workhardened metal

TABLE 1

Approximate annealing temperature ranges in fabrication

Material	Metal Temperature for Additional Cold Working of Fabricated Items*	Average Grain Size mm.	Metal Temperature Producing Fine Grain Structure for Finishing	Average Grain Size mm.
Copper	750-950F	.025	650-800F	.020
Commercial bronze (90 copper, 10 zinc)	925-1175F	.040	775-975F	.025
Red brass (85 copper, 15 zinc)	900-1150F	.040	750-900F	.025
Cartridge brass (70 copper, 30 zinc)	850-1100F	.040	700-850F	.025
Yellow brass (65 copper, 34 zinc)	850-1100F	.040	700-850F	.025
Silicon bronze (97 copper, 3 silicon)	1000-1200F	.050	925-1000F	.020
Silicon bronze (98 copper, 2 silicon)	1100-1200F	.050	925-1000F	.020
Phosphor bronze, grade A (95.75 copper, 4.25 tin 0.15 phosphorus)	1080-1200F	.030	900-1050F	.015
Nickel silver 18% grade A (65 copper, 18 nickel, 17 zinc)	1100-1300F	.035	1050-1150F	.020

Keep annealing temperatures low unless experience dictates otherwise.
**Subject to trial runs prior to actual production.*

continued ▶

so sufficient ductility is restored for further cold working.

Interstage annealing is readily carried out on copper and copper alloys. Table 1 is a chart showing the effect of annealing on various grades of copper and a table giving the approximate annealing temperature ranges of some typical copper alloys.

Interstage annealing is very important and care must be taken to insure that it is properly carried out. If underannealed or heated at too low a temperature (below its recrystallization point) or too short a time, sufficient ductility may not be restored for performing the required additional cold working.

On the other hand, if overannealed or heated at too high a temperature or for too long a period, an undesirable large grain size develops. These large or coarse grains may cause (1) breakage during drawing because of the lowered tensile strength, or, (2) if the part does not break its surface may become so roughened, particularly during drawing, that extra cost may be involved for finishing if the part has to be plated. Excessively high temperatures will also increase the amount of oxidation (scale) of the metal (unless atmosphere-controlled furnaces are used) thereby necessitating longer pickling and dipping operations.

Experimentally, the metal should be annealed at the lowest temperature possible in seeking the proper grain size and smoothest possible surface. Insufficiently annealed work can always be returned to the furnace for re-annealing at a higher temperature. On the other hand, the damage done by over-annealing at too high a temperature cannot be corrected.

Variable factors such as the weight and distribution of load, size and shape of article and or sequence of anneals, type and condition of furnace, play such an important role in determining uniform metal temperatures that it is impossible to set up specific rules the fabricator may follow on time and temperature for annealing copper base alloys. The table listed on approximate temperatures should serve as a guide.

Hot Working

Hot forging can be carried out on drop hammers, power presses or forging machines. Most commonly employed are mechanical presses with one stroke of the press finishing the piece from the heated slug. The action is usually a combination of displacement and extrusion.

From an engineering standpoint the advantages of forgings over castings are important in many applications — greater strength, toughness and freedom from porosity. Forging refines the structure of the metal, makes it more resistant to wear and fatigue. Copper brass forgings are smoother and cleaner in appearance, in many cases cheaper to finish than castings. When design permits, costly machining and assembly operations can be eliminated.

Hot forging is generally more costly than cold forging but is required for making intricate shapes and hollow sections. Also, hot forgings are generally free from mechanical stresses sometimes associated with extreme cold working. Hot working does not workharden copper and copper alloys therefore hot forgings are generally not as strong as cold forgings. Exceptions are some of the aluminum bronzes, in particular the 7% aluminum 2% silicon 91% copper alloy, which has a tensile strength of approximately 90,000 psi in the "as forged" condition.

Many of the copper alloys especially those of the alpha plus beta type (less than 62% copper) can be forged, the greatest demand being for the brasses and particularly the high leaded or readily machinable alloys. Forging brass (Cu 59% Pb 2% Zn balance) is the alloy most commonly used. High tensile brasses (manganese bronze), nickel silver, electrolytic copper, tellurium copper and aluminum bronzes are also hot worked by this method. The table on this page lists the alloys commonly hot forged and pressed as well as usual mechanical properties.

Recent developments in the forging industry have brought about more extensive use of cored forgings made on mechanical presses with closed dies and movable coring punches. Billets are heated to forging temperature and placed between the die halves. The piece is formed when the hot, plastic like metal is extruded within the die to conform to the details of the die. These cored forgings have the same properties as solid forgings plus the fact that parts can be forged with parallel walls with long deep cores, cored four ways on the same plane and with accuracy to 0.005 of an inch.

The material most used for these cored forgings is forging brass but electrolytic copper, tellurium copper, naval brass and aluminum bronzes are also employed.

TABLE 2

Copper alloys commonly forged and pressed

	Electrolytic copper	Tellurium copper	Forging brass	Naval brass	Leaded nickel silver	Al, Silicon bronze
Analysis						
Copper %	99.2	99.5	59.0	60.0	45.0	91.0
Lead			2.0		1.0	
Tin				.75	2.0 Mn	7.0 AL
Zinc			39.0	39.25	42.0	2.0 Si
Nickel		0.50 Te			10.0	
Typical Mechanical Properties As Forged						
Tensile strength psi	32,000	32,000	52,000	60,000	70,000	90,000
Yield strength psi	10,000	10,000	20,000	25,000	45,000	45,000
Elongation % in 2 in.	50	45	35	35	30	30
Hot Forging Temperatures Range Degrees F	1400-1600	1400-1600	1200-1500	1200-1500	1350-1500	1300-1600

Forging is easy with hot-pressed brass

Smooth finish and close tolerances with this new production method

W. H. Irwin

Exclusive DE Feature

Hot-pressed brass and bronze forgings incorporate special advantages for copper-base products. The subject of experiments by metal workers in Britain prior to World War I, techniques have been improved progressively under the impetus of mass-consumption economies. Brass forgings were introduced to Canada in 1952 and domestic output is now of the order of 700 tons a year.

Mr. Irwin, author of this article, is vice-president of Canada Metal Co. Limited, which is located in Toronto.

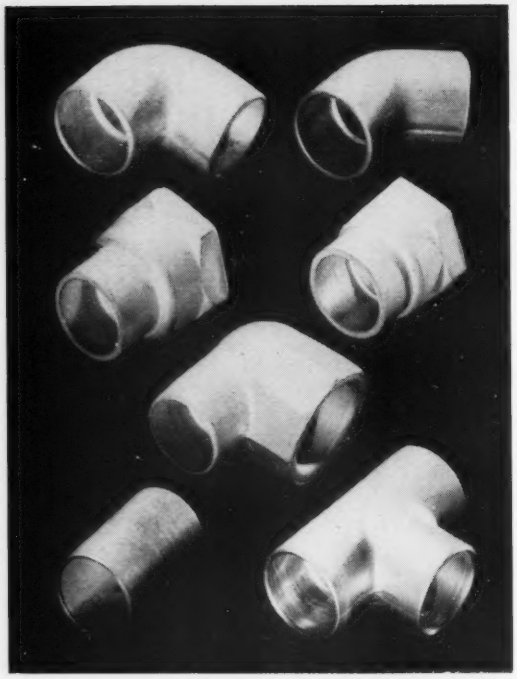
Hot-forged parts are the result of a squeezing movement in two planes. This permits cavities and design not possible with the traditional drop forging, which is the result of a succession of hammer blows.

Brass and bronze forgings are now frequently preferred to sand castings or to fabricated components because:

(1) Smoother finish reduces preplating costs.

(2) Reduced scrap generation both during the hot-forging and machining and finishing operations.

continued ▶



2. These seven precision copper pipe fittings were made in a single pressing by a major Ontario manufacturer.

3. Steam and hot water parts made from hot brass pressings. Freedom from porosity and no inside machining are the two feature considerations.

Copper forging *continued*

(3) More consistency in homogeneity and dimensions. This enables faster chucking, machine speeds and feeds.

(4) Reduction of porosity and inner flaws, and in the number of rejects, the machining of which prior to their discovery is costly when sand castings are used.

(5) Closer tolerances, as little as 0.002 inch. As-pressed parts frequently need no sizing operation, are ready for thread cutting without preliminary forming.

(6) Longer tool life, owing to elimination of sand inclusions and blow holes with their rapid attrition of tools.

(7) Saving of metal. Thinner sections permitted by better physical properties.

(8) Sharp and attractive letters and numerals on as-forged parts.

Difficult shapes now easy

Improvements in forging-press equipment, die design and techniques have enabled the production of difficult shapes, and the use of coring not possible in the early days of hot pressing. Where forgings have replaced conventional assemblies of cast and other types of parts, the number of parts required for fabrication has been cut as much as 50% and the number of assembly operations by an even larger percentage.

First made commercially as an ammunition-fuse part in World War I, the pressing has expanded its applications to several fields. These include refrigeration, automotive parts, compressed-gas equipment, engineering and aviation, hydraulic lines, radar and electronics. The use of pressings has received considerable momentum from the growing popularity of copper tubing for domestic water and heating lines. The connectors joining the tubing are generally hot pressings.

Brass pressings involve this sequence of operations:

- The heating of extruded or chilled-cast and cleaned bars and billets to a semiplastic state. (Cold slugs can sometimes be used.)

- The feeding of the bars or billets to a position between steel dies in a press or hammer. In some cases, the part is formed in one operation; in others by stages, with severe die impressions.

- The subjecting of the billet to pressure, causing the metal to flow and fill out the contour of the die. Excess metal is known as "flash" and is subsequently trimmed away.

Brass pressings are generally used for irregularly shaped parts in one plane. It is, however, possible to produce cavities in two planes through the use of split dies, coring dies and sidearms.

Limits to sizes and materials

The limits to the size of pressings are determined: (1) on the minimum side — by the size of the billet which it is practical to handle, which is dependent partly on the experience of the maker and his operators and (2) on the maximum side—by the capacity of the presses available for the type of part wanted. On the minimum

Table I

Alloys commonly hot-pressed or forged, and expected mechanical properties for the forged parts

Metal	Tensile strength 1000 psi	Yield strength 1000 psi	Pct elongation in 2 in.	Rockwell hardness	Nominal composition Cu	Zn	Sn	Fe	Si	Al
Electrolytic copper	30 to 38	8 to 10	45 to 50	25 to 65 (F)	99.92	...	...	...	...	...
Deoxidized copper	30 to 38	8 to 10	45 to 50	25 to 65 (F)	99.94	...	...	...	...	...
Muntz metal	50 to 65	22 to 30	40 to 50	45 to 60 (B)	60.0	40.0	...	...	...	...
Forging brass	50 to 65	22 to 30	35 to 50	45 to 60 (B)	60.0	38.0	...	2.0	...	...
Naval brass	55 to 68	25 to 35	30 to 45	50 to 65 (B)	60.0	39.25	0.75	...	...	...
Leaded naval brass	55 to 68	25 to 35	25 to 40	50 to 65 (B)	60.0	37.5	0.75	1.75	...	...
High-silicon bronze (A) ..	50 to 65	18 to 24	50 to 70	35 to 50 (B)	96.0	...	...	...	4.0	...
Low-silicon bronze (B) ..	40 to 55	16 to 22	50 to 70	30 to 45 (F)	97.5	...	1.0	...	1.5	...
Aluminum bronze	75 to 90	33 to 40	15 to 30	75 to 90 (B)	89.5	*	*	*	...	9.0
Aluminum-silicon bronze.	90 to 98	65 to 70	15 to 25	85 to 95 (B)	91.0	...	...	...	2.0	7.0
Manganese bronze (A) ..	65 to 75	35 to 45	25 to 45	65 to 80 (B)	58.5	39.2	1.0	1.0	...	...
Manganese bronze (B) ..	85 to 105	55 to 75	15 to 30	85 to 100 (B)	65.5	23.3	...	3.0	...	4.5
Nickel silver, 10 pct	90 to 100	35 to 45	20 to 30	65 to 75 (B)	45.0	45.0	...	...	10.0 pct Ni	

* Fe, Sn, Mn, Zn may be present to 1.5 pct, remainder of analysis.

Table II — Commercial dimensional tolerances

Copper and copper-base alloy forgings (hot pressed)

Small forgings (weight up to 2 lbs., incl.)*	Copper	Muntz metal	Forging brass	Naval brass	Leaded naval brass	Manganese bronze (A)	High silicon bronze (A)	Aluminum silicon bronze	Nickel silver 45-10
Forging types									
1. Solid	.010	.008	.008	.008	.008	.008	.012	.010	.008
2. Solid, with symmetrical cavity ..	.010	.008	.008	.008	.008	.008	.012	.010	.008
3. Solid, with eccentric cavity	.012	.008	.008	.008	.008	.008	.012	.012	.008
4. Solid, deep extrusion	.012	.010	.010	.010	.010	.010	.014	.012	.010
5. Hollow, deep extrusion	.012	.010	.010	.010	.010	.010	.014	.012	.010
6. Thin section, short, (up to 6″ incl.)	.012	.010	.010	.010	.010	.010	.014	.012	.010
7. Thin section, long, (over 6″ to 14″ incl.)	.015	.015	.015	.015	.015	.015	.020	.015	.015
8. Thin section, round	.012	.010	.010	.010	.010	.010	.014	.012	.010
Draft angles outside and inside 1° to 5°	½°	½°	½°	½°	½°	½°	½°	½°	½°
Machining allowance (on one surface)	1/32	1/32	1/32	1/32	1/32	1/32	1/32	1/32	1/32
Flatness (max. deviation per inch) .	.005	.005	.005	.005	.005	.005	.005	.005	.005
Concentricity (total indicator reading) ..	.030	.020	.020	.020	.020	.020	.030	.030	.030
Nominal web thickness	5/32	⅛	⅛	⅛	⅛	⅛	3/16	5/32	⅛
tolerance	1/64	1/64	1/64	1/64	1/64	1/64	1/64	1/64	1/64
Nominal fillet & radius	3/32	1/16	1/16	1/16	1/16	1/16	⅛	3/32	1/16
Tolerance	1/64	1/64	1/64	1/64	1/64	1/64	1/64	1/64	1/64
Approximate flash thickness	1/16	3/64	3/64	3/64	3/64	3/64	5/64	1/16	3/64

* For tolerances applicable to forgings weighing more than two (2) pounds, consult the producers of forgings.. Tolerances are plus and minus; if tolerances all plus or all minus are desired, double the values given (in inches except as shown)

continued ▶

size, pressings have been made weighing as little as 3 oz; on the maximum size, pressings to 14 pounds in weight and eight inches in diameter have been made in Canada.

Any copper-base alloy which can be extruded can be pressed by the hot-forging process, although in practice only about 10 are regularly used.

The most commonly used brass for pressing is the Duplex alloy, containing 58% copper, 2% lead and 40% zinc, generally embraced by the British Standard specification 218 or ASTM B 124-alloy 2.

Forging temperature for brasses and bronzes is 600C to 750C. The plastic stage for various alloys can be obtained from the relevant-phase diagram or constitution diagram.

Control of heating temperature is of great importance. A billet which is too cool will result in severe added stresses during the squeezing process, and can reduce quality and tool life. On the other hand, an excessively hot billet will undergo separation of the grain structure. The part will be rough, with the surface appearing crystallized.

Of equal importance to the heating of the billet is the heating of the dies prior to the hot-pressing operation. A good average for this is 250C. The dies are heated, otherwise heat would be transferred to them during the stamping process, resulting in distortion and subsequent cracking.

Forging operation requires skill

The actual forging operation calls for a good deal of skill on the part of the operator in adjusting the stroke of the press and the pressure of the squeeze applied, depending on the size of the part, the alloy being forged and the working temperatures. Only thus is it possible to produce at a speed in keeping with the expected economics of the hot-forging process.

Choice of the appropriate press for a given part is of vital importance. There are mainly three types of press. Drop hammers have been used for some basic and crude forgings. It is, however, necessary to use crank presses and eccentric presses for the introduction of cores. With the crank press it is possible to make parts with parallel sides, with no draft angle, and this helps to avoid machining. These dies, of course, are more costly. Made from material of round section, they are comprised of more than two pieces. Many parts of the dies slide over one another to enable the plastic brass to be pushed to flow in the required direction, or to be extruded to shape. Ejectors are a necessary part of the crank press-die design, and they accelerate the operation of pressing.

The pressing operation involves the use of some lubrication for good metal flow and ejection of the part. In this area the judgment of the press operator is of great importance. A pressing can be made or marred by the type of lubricant and its application, although usually a high-grade graphite grease is satisfactory.

Three main die designs

Die design falls into three classifications:

1. Open, with one plane of parting.
2. Extrusion. The metal flows into an annular space between the punch and the die cavity.
3. Split. These dies permit the forging of flanges and other projections, which could not otherwise be removed from the dies.

The greater strength and toughness of hot forgings and pressings is rightfully attributed to a compacting and refinement of the grain, or fibre of the material by the forging process. In parts designed for strength, the grain or fibre should be worked into a position parallel to the principal stresses likely to occur in the parts. The grain should never be permitted to run transversely to the axis of the greatest bending stress. Since hot forgings and pressings are made from brass rod and shapes in which the fibre already runs longitudinally, the arrangement of the fibre in the finished part should assure a product of maximum strength.

Dies are made of hardened steel, accurately machined and polished and anticipate the behavior of the metal under heat and pressure.

Good die design makes allowance for shrinkage of the forging in cooling and for its release from a vertical cavity-wall die. The draft angle necessary for freeing the forging from the die is from one to five degrees (Commercial Dimensional Tolerances), one degree being equal to 0.0175 inch slope per inch of depth. Draft tolerance is ½ degree. Design should provide adequate radii on inside and outside fillets, avoid undercuts and rapid changes in section. Cavity walls should not be necked down or so close together as to restrict the free flow of metal.

Since the quantity of metal in the forging billet must always exceed that of the finished forging, the die contains a gutter or relief area for excess metal or flash. Controlling the amount of flash sometimes involves prestamping of an extrusion of roughly the same section as the component.

Cost conscious industry

From the foregoing it is apparent that the manufacture of hot forgings has been carried to a high degree of efficiency. Since the industry has had to supplant competitive processes, it is extremely cost-conscious. The cost factors in forging are:

1. The number of parts to be pressed.
2. The composition of the alloy.
3. The design of the part.
4. Projected fabrication methods.

The best way to determine the applicability of the forging process to a given part is to consider:

Quantity. This involves weighing the number of parts to be made against anticipated die life. Where runs are very large, a master die can be made and working dies reproduced from it.

Material. Selection will take into consideration the physical requirements of the alloy, its adaptability to fabrication, machineability, ease of joining to other metals, and the type of finish desired.

Design. Will take into consideration the economics of the pressing process against other processes, emphasizing the cost of rejects and of secondary machining operations.

Determination of the cost of pressings and the advisability of using them is basically a matter for close-in cost accounting. ★

1. Phosphorized copper head for distillation column being welded using argon shielded tungsten-arc. Cu. 372 filler.

Mechanical joining of copper is simple

Brazing — soldering — welding — all the well-known processes are used

J. Imperati

Exclusive DE Feature

Practically all metals can be joined with varying degree of ease and practicability, by means of welding, brazing and soldering processes. Copper and its alloys are no exception.

The comments offered here are generally true for most of the usual applications. However, it must be emphasized that mechanized welding and use of elaborate fixturing devices often make it possible to obtain good results with processes and metals that usually are not compatible. It is therefore urged that expert advice be obtained in cases where welding is desirable but appears to be impracticable.

Soldering

The American Welding Society (AWS) defines soldering as a group of processes employing alloys melting below 800F applied to metals which are not in themselves melted. General purpose solders are the well-known tin-lead alloys. However, many other combinations, such as tin-antimony, tin-silver, tin-zinc, lead-silver, and cadmium-silver have been in wide usage for service at elevated temperatures, for soldering aluminum, and for other special purposes.

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With fluxes available in a wide variety ranging from non-corrosive rosin to the very active chloride mixtures, it is possible to solder successfully practically all the copper-based metals. The exceptions are the aluminum bronzes, and for consistently good results it is advisable to plate them first with solderable metals.

Brazing

The AWS definition of brazing is the joining of metals which themselves are not melted, by alloys melting at temperatures above 800F. Thus, it covers the brazing of brass with silver alloys that melt at temperatures as low as 1,200F, and the brazing of cupro nickels and ferrous metals with copper which melts at 1,976F. The definition also calls for joints designed with closely fitted surfaces so that the molten brazing alloy can be drawn into them by capillary attraction. Brazed joints depend for their mechanical properties on the shear strength of thin films of brazing filler metals, whereas welds derive their properties from the cross-sectional tensile strengths of the metals that are fused to make them.

Copper, and the copper alloys, with the exception of the aluminum bronzes, are readily brazed with the standard silver and copper-phosphorus filler metals of ASTM B260. The aluminum bronzes develop very re-

continued ▶

fractory oxides on heating and, while special fluxes have been developed to assist in brazing them, extreme care must be exercised in cleaning them before fluxing and heating.

The silver alloys are predominantly silver and copper, and many are alloyed with zinc and sometimes with cadmium. They may be used on all the copper-based metals. The copper-phosphorus types sometimes have silver added. They are used on all the copper-based metals, but are not recommended for joining the cupro nickels because the formation of brittle nickel-phosphorus compounds may impair joint qualities.

Brazing is the preferred choice for joining any of the leaded alloys. Brazing is done without melting the base metals, so it avoids the problems raised by the porosity and cracking that usually accompany attempts to weld these alloys.

Welding

All of the lead-free copper-based metals can be joined by welding, using one or more of the available welding processes. Oxyacetylene and electric-arc welding usually employ filler metals to complete the joints, and the standard welding rods and electrodes described in ASTM B259 and B225, respectively, are listed in Table 1. Electric resistance welding does not require the addition of filler metals to the joints.

The selection of a joining process is influenced by many factors, among which are the advantages and limitations of the processes and the limitations, if any, of the metals. These factors, as they apply to the choice of welding process, are described briefly in the comments that follow under the major base metal group headings.

Group 1. The coppers

Two classes of copper are available and must be considered as widely different if they are to be brazed or welded by arc, flame or furnace processes. They are the oxygen-bearing coppers, like electrolytic tough pitch, and the oxygen-free ones, like phosphorized copper.

In the first, oxygen is present as minute particles of cuprous oxide. In the wrought metal this oxide is scattered uniformly throughout and does not affect mechanical or electrical properties. However, as is well known, hydrogen easily diffuses into hot copper, and its reaction with the oxide results in the familiar embrittlement or "gassing" phenomenon. Welded or brazed joints in oxygen-bearing coppers can show seriously reduced joint properties due to this process.

The oxygen-free coppers are not saddled with this source of weakness, therefore brazing and welding can be done on them with full confidence in the results. It is recommended that whenever the maximum joint properties are required, phosphorized copper base metal be used instead of electrolytic tough pitch copper.

The inert-gas shielded arc processes have proven to be the most efficient means for welding copper, and are used almost exclusively now to the exclusion of other arc processes and oxyacetylene welding. In tungsten-arc welding helium is the preferred shielding gas. It increases weld-metal fluidity, improves fusion of weld and base metal, and lowers the temperature level required when preheat has to be employed. However argon can also be used satisfactorily if allowance is made for higher heat input. In consumable electrode welding the shielding gas is usually argon; helium produces too much spatter and, if used at all, it would only be in an argon-helium mixture.

Regardless of the welding process used, sound welds cannot be produced with ordinary copper filler metal. The filler metal must be an alloy with small additions of elements like silicon, manganese and tin to suppress porosity and improve its strength. A patented alloy of this type which has been successfully used for some years now has nominal copper content of 98.8%, and so avoids any objections that may be raised as to its corrosion resistance. It also is the only filler metal that will produce code-quality joints; when used on phosphorized copper the welds made with it develop mechanical properties that meet the requirements of Section VIII of the ASME Boiler and Pressure Vessel Code. It is marketed in straight lengths and as spooled electrode wire.

Preheat is usually required on thickness above 3/16 in. When helium is used for shielding the preheat temperatures range from 500 to 1,000F depending on metal thickness. With argon the preheat temperatures may have to reach 1,400F on heavy work. Preheating, of course, will oxidize the work, so a light application of flux before heating starts, and also before welding, will help overcome the handicap that the oxidized surfaces may present.

Oxyacetylene may be done successfully on phosphorized copper. It has been almost completely supplanted by inert-gas arc welding but is used occasionally on thin metal because it offers somewhat easier control. The alloyed filler metal described above is also the most successful for oxyacetylene welding.

Carbon-arc welding is an economical arc process that has sometimes been used on applications that do not require welds of high copper content. It is only done with filler rods of copper-silicon alloy or phosphor bronze.

Metal-arc welding with fluxed electrodes is not successful on copper. The high heat requirements result in violent spatter and very poor control and the weld metal usually proves to be porous and full of slag and flux inclusions.

Resistance flash-butt welding is successfully performed on copper wires and bars. However, resistance spot and seam welding of sheet metal is practically impossible due to the high heat requirements and because the electrodes weld very easily to the work.

Group 2. Low zinc alloys

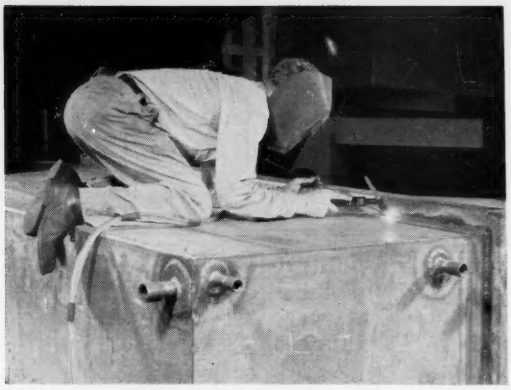
Brazing is preferred to welding on these alloys because it is more easily done, results are consistent, and it avoids porosity often developed in welding.

Oxyacetylene welding may be done but it requires use of copper-silicon alloy filler rod to make sound joints with good color match.

Arc welding is handicapped by zinc vaporization and porosity. However inert-gas tungsten-arc, and carbon-arc welding may be done with good results if copper-silicon alloy filler rod is used.

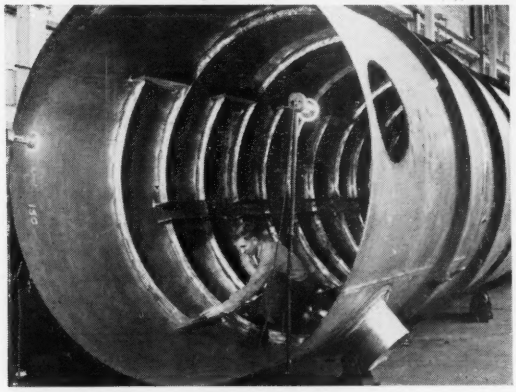
Metal-arc welding with fluxed electrodes is not recommended. Spatter and poor control result in welds with voids and inclusions.

Resistance flash-butt and spot welding is done successfully on the lead-free alloys. Seam welding is not practicable because of high heat requirements.

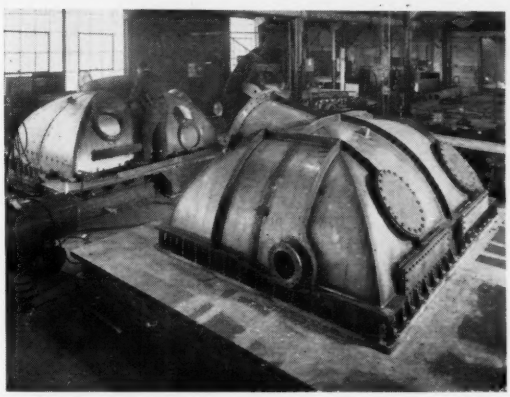


2. Welder climbs on top of the job—a degreasing tank.

3. Fifteen thousand gallon Everdur tank for brewery.



4. Fractionating tower 30 feet long and 10 feet in diameter is made of phosphorized copper—and all-welded.



5. Water boxes for steam condensers on an aircraft carrier call for copper plate and steel flanges.

Group 3. High zinc alloys

Color matching welds in these alloys may be made by oxyacetylene welding with low-fuming bronze rods. However, if corrosion resistance is important, as on Admiralty metal, welding rods of copper-silicon alloy must be used, or the joints must be designed for brazing with silver or copper-phosphorus alloys.

Arc welding is difficult due to zinc vaporization. However, with copper-silicon filler rods it is possible to weld relatively thin metal by the inert-gas tungsten-arc and carbon-arc processes.

Resistance flash-butt welding of wire and bar, and resistance spot welding of sheet metal are done successfully on the lead-free alloys. Seam welding is not practicable.

Group 4. Nickel silvers

Brazing is the most easily performed joining process and is most widely applied in architectural uses.

Color matching welds are possible on some alloys by oxyacetylene welding with nickel bronze filler rods.

Arc welding is seldom done. It is necessary to use zinc-free rods, such as copper-silicon alloy, and the welds then are too conspicuous because of their color.

All forms of resistance welding can be done successfully on the lead-free nickel silvers.

Group 5. Copper-silicon alloy

The copper-silicon alloy filler metal used for all the processes that require it is practically of the same composition as the usual base metals, so that color match is excellent and corrosion resistance identical.

The inert-gas shielded arc processes are the most widely employed and with them it is possible to make joints whose properties meet the requirements of Section VIII of the ASME Code. Shielding gas for tungsten arc welding may be helium or argon, but argon is used for consumable-electrode welding.

Oxyacetylene welding, though seldom done now, produces excellent results.

Carbon-arc welding is an economical and easily employed process, and is occasionally used where it is not necessary that the joints develop the high properties available from inert-gas arc welding.

Metal-arc welding with fluxed electrodes is seldom employed except for applications where only moderate joint quality is required. Spatter, poor control, and inclusions make weld-metal deposits of inconsistent and questionable quality.

All the resistance welding processes can be employed with excellent results.

Group 6. Phosphor bronzes

It is not possible to make welded joints in these alloys and develop the strength of the annealed base metals. Therefore, where possible it is advisable to consider use of a brazing process.

However, if welding must be done, then moderately good results can be obtained by carbon-arc or inert-gas tungsten-arc welding with the standard copper-tin weld-

continued ▶

ing rods, or by metal-arc welding using the standard fluxed copper-tin alloy electrodes. Care must be taken with the latter to minimize the production of voids and inclusions in the weld metal, and preheating, especially on heavy sections, will help to do so.

Oxyacetylene welding is not satisfactory because of extreme weld-metal porosity.

Resistance flash-butt welding is successfully done on wire and rod, and so is resistance spot welding on sheet. Seam welding is extremely difficult due to high heat requirements and welding between electrodes and work.

Group 7. Copper-nickel alloys

Welding filler metals for these alloys are all based on the 70-30 cupro nickel composition.

Fluxed electrodes that perform well in all positions are available for metal-arc welding. They produce excellent results on all the copper-nickel alloys; strength is more than what is needed on the 80-20 and 90-10 base metals, and corrosion resistance is not impaired by the difference between weld and base metal compositions.

A specially alloyed filler metal is employed for inert-gas arc welding. It develops the full strength of the annealed 70-30 base metal and can be used with excellent results also on the other copper-nickels. It is marketed as straight lengths of welding rod and as spooled electrode wire.

Another special welding rod is available for oxyacetylene welding of the 70-30 alloy. It may also be used with good results on the other copper-nickel alloys.

All resistance welding processes are successfully applied in joining the copper-nickel alloys.

Group 8. Aluminum bronzes

The copper-aluminum filler metal alloy shown in Table 1 is generally used in welding the aluminum bronzes. There are others with higher aluminum and iron contents, but they appear to have but little advantage, if any, in quality of deposited weld metal, and are more costly to produce.

The aluminum bronzes develop refractory oxides very easily on heating and welding operations and are severely hampered by them. However, the inert gas consumable-electrode process overcomes this handicap very well and should be considered first choice whenever it can be efficiently applied. Argon is used for the shielding gas. Preheating is generally not necessary.

Inert-gas tungsten-arc welding is useful where welds can be completed in one pass. Fluxes are offered for use with this process where interfering films develop on multipass welds in heavy sections. Helium may have a slight advantage over argon for the shielding gas, and some users believe that alternating current is more effective than the straight-polarity direct current usually employed for this process.

Fluxed rods are available for use with the carbon-arc process. There is apt to be some spattering of the weld metal because it is readily superheated under the insulation produced by the slag on the weld pool, and this can produce voids and inclusions in the joints.

Fluxed electrodes are available for metal-arc welding. Their action is violent and erratic, especially if the flux coatings are not kept dry, and the weld deposits tend to show considerable porosity and entrapped slag.

Oxyacetylene welding is not practicable.

All the resistance welding processes can be applied; spot and seam welding of sheet should not be difficult if the surfaces are free of oxides **before welding is attempted.**

The foregoing is a brief summary of what is practicable with the well-known joining processes and the more commonly used copper-based metals. As indicated, many other combinations are possible, and the members of the copper industry will be glad to advise for special conditions.

Table 1
Standard welding rods and electrodes

Name	AWS Classification	Composition-percent (max. except as noted)									
		Cu min.	Zn	Sn	Si	Mn	Fe	Ni	Al	P	Ti
Copper	RCu, ECu	98.0		1.0	0.5	0.5				0.15	
Copper-silicon (silicon bronze)	RCuSi-A, ECuSi	94.0	1.5	1.5	2.8 / 4.0	1.5	0.5				
Copper-tin	RCuSn-A, ECuSn-A	93.5		4.0 / 6.0						0.05 / 0.35	
Phosphor bronze	ECuSn-C	90.6		7.0 / 9.0							
Copper-nickel	RCuNi, ECuNi	66.3	1.0	1.2	0.25	1.25	0.40 / 0.70	29.0 / 33.0			0.50
Naval brass	RCuZn-A	57	bal.	0.25 / 1.00							
Low-fuming bronze (nickel)	RCuZn-B	56	bal.	0.75 / 1.10	0.04 / 0.15	0.01 / 0.50	0.25 / 1.25	0.2 / 0.8			
Low-fuming bronze	RCuZn-C	56	bal.	0.75 / 1.10	0.04 / 0.15	0.01 / 0.50	0.25 / 1.25				
Nickel bronze	RCuZn-D	46	bal.		0.04 / 0.25			9.0 / 11.0		0.25	
Copper-aluminum (aluminum bronze)	RCuA-A2, ECuA1-A2	89			0.10		1.5		9.0 / 11.0		

Design Engineering DATA SHEET

Physical Properties of Copper

Exclusive DE Feature

R. A. Wardell

Canada's copper is refined by the electrolytic process which is capable of refining the metal to a very high degree. The purity of the product generally exceeds 99.97%.

Electrolytic refining is carried out in tanks of acid-proof construction through which is circulated warm diluted sulphuric acid and copper sulphate. The thick anodes, which have already passed through other processes to bring them to about 99% purity, are suspended in the tanks and are inter-leaved with thin sheets of pure copper called "starting sheets". On the application of an electric current the anodes slowly dissolve and pure copper is deposited on the starting sheets, which thus act as cathodes.

Subsequently the cathodes are either sold to industry or are re-melted in reverberatory or direct arc-type electric furnaces and cast into regular shapes such as horizontally cast wire bars, ingot bars and ingots, or special shapes which include vertically cast wire bars, cakes and billets.

Two common types

Two types of copper are in most common use. These are known as electrolytic tough-pitch copper and de-oxidized copper.

Electrolytic tough-pitch copper, contains a controlled amount of oxygen in the range of 0.02 to 0.05% and has a minimum electrical conductivity of 100% I.A.C.S. It has long been the standard type of commercial wrought copper used for the production of wire, rod, plate, sheet and strip.

Deoxidized copper, is produced by introducing phosphorus as a deoxidizing agent to assure the removal of all of the oxygen. Phosphorus deoxidized copper with residual phosphorus is generally characterized by high softening temperature, free scaling properties, and resistance to hydrogen embrittlement. These properties are particularly desirable when the fabricated product is to be welded or brazed. Hence, the deoxidized copper finds most common use in pipe and tube applications. The phosphorus additions may be varied to meet the particular demands of the fabricator. In general however these fall into two classes namely:

D.H.P.—High residual phosphorus copper, the deoxidized copper with residual phosphorus in the range, 0.013 to 0.040%. This is sufficient to decrease appreciably the conductivity of the copper. Material in this class will have conductivity of 75 to 95%.

D.L.P.—Low residual phosphorus copper, the deoxidized copper with residual phosphorus in the range, 0.004 to 0.012%. In this case the residual phosphorus is usually too small to decrease appreciably the conductivity of the copper. In fact, at the upper limit of 0.012% phosphorus, the conductivity is usually in the order of 96.6%.

Basic properties of copper

Description

Copper is a metallic element with atomic number of 29. It is the only red colored metal, is non-magnetic, and may be used in its pure form, or alloyed with many other metals to provide a widely diversified range of physical properties.

Specific gravity and density

The specific gravity of copper as used for drawn wire and tube is usually taken as 8.89 at 20C. with weight as 0.321 lb/cu in. or 555 lb/cu ft. The weight of commercial copper in the cast condition is normally taken as about 0.31 lb/cu in.

Melting point

The melting point of copper is 1981 F. When melted in an oxygen-rich atmosphere, copper may absorb oxygen and its melting point will be lower than the above figure, but not less than about 1949 F.

Boiling point

The boiling point of commercial copper is about 4217 F. For pure copper (no oxygen or phosphorus, maximum impurities 0.002%) the boiling point is 4703 F.

Tensile strength

The mechanical properties of copper, and indeed of all metals and alloys, are dependent to a very great extent upon physical condition, and differ widely according to whether the material is "as cast" or whether it has been "worked", and also upon the extent and manner of working. Copper as cast has a tensile strength of about 11 to 12 tons/sq in. Rolling, forging or other types of hot or cold working, followed by annealing, modify the structure of cast copper, and raise its tensile strength. Hence, in the wrought and annealed condition the tensile strength of copper is upwards of 14 tons/sq. in. In cases where copper is annealed after severe cold working, tensile strength often exceeds 16 tons/sq in. Very heavily cold-worked copper, which is generally in wire form, may possess a tensile strength up to 30 tons/sq in. which is about the limiting value encountered in practice.

Elongation

Elongation figures for copper vary widely with its physical condition. On 2″, figures for cast copper are

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25% to 30%, for cold-worked copper from 5 to 20%, for copper annealed after cold-working from 50 to 60%.

Shear strength

The shear strength of annealed copper is about three quarters the strength in tension, falling to approximately one half of the tensile strength for heavily cold-worked material.

Temper of copper

The figures above have shown the variance in physical properties that are possible, depending on whether the metal is in the cold-worked or the annealed condition. Basically, as the amount of cold-working increases, so does the tensile strength and hardness increase, but at the same time there is a reduction in ductility.

Many steels may be hardened by quenching and afterwards softened to the required temper by re-heating at various temperatures, whereas for copper the process is begun from the softened, or annealed, condition, and the tempers obtained by submitting the metal to different degrees of cold-working. For making a given product a temper should be chosen which will permit the metal to have the required hardness after processing. Two of the important advantages of copper, are the large amount of "working" possible before the metal becomes hard, and the simplicity of the annealing process. For extreme "heavy-working" operations, annealing may readily be included at the necessary intervals to produce the desired result.

Modulus of elasticity

Young's Modulus for copper has been assessed by various investigators at values between 16 and 19×10^6 lb/sq in. The value which is usually accepted for hard-drawn copper in wire, rod, and other forms, such as are used for electrical purposes, is 18×10^6 lb/sq in.

TABLE 1

Some properties of metals

Metal	Relative Electrical Conductivity at 20°C.	Relative Thermal Conductivity at 20°C.	Coefficient of Linear Expansion per °C. at 20°C. $\times 10^{-6}$
Silver	106	108	19
COPPER	**100**	**100**	**16.6**
Gold	72	76	14
Aluminium ...	62	56	23
Magnesium ...	39	41	26
Zinc	29	29	30
Nickel	25	15	13
Cadmium	23	24	31
Cobalt	18	17	12
Iron	17	17	12
Platinum	16	18	9
Tin	15	17	21
Lead	8	9	28

Electrical properties

Copper has long been the choice of electrical engineers, having a comfortable margin with respect to conductivity over all the other common metals. Only silver has a higher conductivity. The international standard for electrical conductivity, I.A.C.S., is based on the electrical conductivity of copper being 100%, and great care is taken by the copper producers in their quality control of purity, to ensure this exceptionally high conductivity rating. The figure of 100% I.A.C.S. does not represent the highest possible conductivity, and copper in the annealed condition frequently attains a conductivity of 101% or even 102% I.A.C.S. The relative electrical conductivity of various metals is shown in Table I. The resistivity of electrolytically refined copper is usually taken as, 0.15328 international ohm-gram/meter² at 20 C.

As already pointed out, an exceptionally high standard of purity is maintained to give, as its return, an exceptionally high standard of conductivity. However, fractional percentages of other elements may be added to enhance certain properties for electrical work. Basically, cadmium will increase wear resistance, chromium gives greater strength, silver gives higher creep resistance at elevated temperatures, and tellurium improves machinability.

Thermal properties

As may be expected, the natural relationship between electrical and thermal conductivity, places copper in the exceptional ranks with regard to this latter property. Again it holds a comfortable margin over other common metals and is exceeded only by silver. The thermal conductivity for the purest forms of commercial copper possessing an electrical conductivity of almost 102% I.A.C.S., is 0.941 calories/sq cm/cm/sec/°C/at 20 C. For copper with 100% conductivity a value of 0.92 c.g.s. units may be used. Relative thermal conductivity values for commercially pure metals are included in Table I.

Thermal conductivity is reduced by the presence of impurities in approximately the same manner as is electrical conductivity, but there is a slight deviation from a general relationship of these two properties.

The specific heat of copper at normal temperatures is 0.092. This value increases linearly with rise of temperatures, so that at 300 C it becomes 0.098, and 1000 C, 0.13. The co-efficient of linear expansion of copper over a temperature range between 20 and 100 C is usually taken as 16.6×10^{-6} per C, or 9.22×10^{-6} per F. Relative co-efficients of linear expansion of common metals are shown in Table I.

Summary

The foregoing is a brief outline of the fundamental facts and figures on the physical properties of copper. Other properties of equal importance to the design engineer, such as ease of fabrication and resistance to various types of corrosion were not considered in the limited space. Nor did we introduce the vast field of copper alloys, which now number in the region of 750, each designed to do a particular job with greater efficiency.

The greater part of the work of the Canadian Copper & Brass Development Association is in the distribution of highly technical literature, and the answering of technical questions as they apply to particular applications. Our services are available to all interested, free of charge, and we are ready to assist in every possible way at any time.

1. One of the most critical and selective applications of copper in the electrical industry is magnet wire.

Copper is ideal electrical conductor

Use in magnet wire calls for close attention to insulation, says expert

K. Alexander, P.Eng.

Exclusive DE Feature

Copper is essential to the electrical industry as we know it today and likewise the electrical industry is probably the copper industry's best customer. The reason for this preference for copper is, of course, its high electrical conductivity. Copper has the highest electrical conductivity of any base metal, being exceeded in this respect only by silver.

In addition to the conductivity, other properties which make copper so valuable to the electrical industry are its excellent malleability, tensile strength and yield strength, ease of soldering and corrosion resistance. Most of the copper used in the electrical industry is in the form of round wire. The wire is strong enough to be self-supporting under most applications and can be readily joined by mechanical methods or by soldering.

One of the most critical and selective applications of copper in the electrical industry is for the manufacture of magnet wire. In this application careful consideration must be given to the bare conductor material and its method of manufacture in order to meet the quality demand of the market.

Magnet wire defined

Magnet wire, as conceived by Joseph Henry more than 125 years ago, is a continuous length of conducting metal. It is capable of being wound either by form or in random manner on a supporting arbor, or in or on an insulated ferromagnetic armature or core for the express purpose, in the completed device, of carrying electrical current for the establishment of an electrical field associated with the magnetic circuit on which it is wound. The insulation on magnet wire is present only to separate individual turns so that only one wire path is open to the passage of electrical current. Line voltage stresses are not borne by the magnet wire insulation, but by added supporting insulation in the form of solids (such as tapes, varnishes and cast-resin blocks), liquids (such as oils), and gases (such as sulfur hexafluoride).

Since magnet wire is likely to be the major source of heat (I^2R loss in the conductor) the magnet wire insulation is most likely to be subjected to the hottest spot temperature in a given device. In addition, the insulation is normally in a position least able to be cooled and is dependent on associated insulations or media to dissipate heat.

The high dielectric strength of many of the more

Mr. Alexander, author of this article, is magnet wire engineer with Canada Wire and Cable Company, Simcoe, Ont.

recent magnet wire insulations has tempted some users to ignore the basic definition of magnet wire and to eliminate some portions of supporting insulations in the quest for economy of design. This is considered unwise for the following reasons:

(1) Magnet wire insulation, unless in very heavy coatings, is permitted a number of unavoidable discontinuities of microscopic size per hundred feet of conductor.

(2) Unavoidable winding damage may occur.

(3) Contamination may cause failure where the wire enamel is relied on for high voltage insulation.

(4) Surge voltages may exceed the dielectric strength of the film.

In the magnet wire definition are the words "capable of being wound." In this respect, such properties as conductor hardness, insulation flexibility, abrasion resistance and adherence are very important as a serious deficiency in any one property will drastically limit their application in coils for the electrical industry.

Conductors

No other usable metal except silver and gold has a conductivity as high as that of copper. With properties unmatched by other metals, copper has always satisfied the majority of needs of the electrical industry. For magnet wire applications bare copper conductors in round, square or rectangular shapes are rolled and drawn from a copper bar. In the drawing operation the rod or wire is pulled through a series of integrated dies by a series of stepped-up power blocks to compensate for the increasing length of wire. During this operation a copious supply of lubricant is necessary and soap solutions of varying fat content are used. In this manner, round copper wire is produced for magnet wire varying in diameters from .1620 in. to .0020 in. and finer. After the drawing operation, the copper wire produced has been work-hardened and it is necessary to use systems of intermediate and final anneals to produce the ductility required in the final product.

For all magnet wire applications great care is taken in the selection and processing of copper into either round or rectangular wire. Conductor hardness in the finished product often creates winding difficulties. This is most acute in specially shaped coils where spring-back problems make a soft wire a necessity. Space factor problems in many applications also demand a soft wire. This practice, however, can be overdone where very soft magnet wire is excessively stretched. For adequate mechanical characteristics not only should the tensile strength be in the range of 35,000 to 38,000 psi, but the elongation and bendability should be as high as possible. Thus, the best performance characteristics may be expected from wire showing the largest area under the load elongation curve. In rectangular magnet wire some types of bending create serious problems in flexibility and adherence. This is particularly brought out in the edge-wise bending of rectangular magnet wire where the ultimate in copper quality and processing is required to produce the desired results.

In recent years there has been a great deal of impetus to develop magnet wires that are suitable for use in equipment operating at elevated temperatures. This is one area in which copper has been challenged as a conductor.

It is known that substitution of other metals such as aluminum and nickel for copper as a conductor can, in some cases, result in a higher thermal stability of the magnet wire. This is explained by the fact that copper shows some catalytic action in the aging of enamel while aluminum and nickel do not. Since this advantage is not completely realizable due to decreased conductivity of the conductor, very promising work is being done on aluminum conductors with a layer of aluminum oxide under the enamel coating and on copper conductors with a thin coating of aluminum paint under the enamel coating.

Magnet wire insulations

Magnet wires may be grouped into three categories based on the type of insulation used. These are film-coated, fibre covered and film taped. Various combinations of these insulations may be obtained as the demand arises.

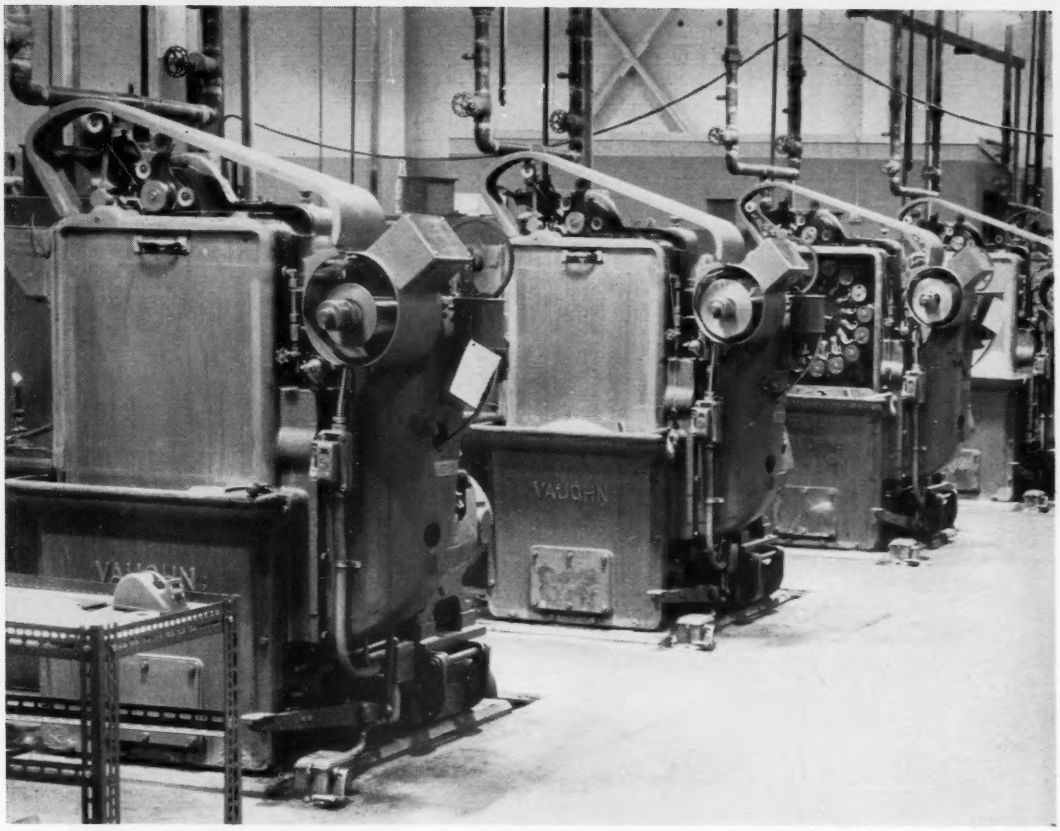
▸ **Film coated types.** Produced by applying multi-coats of thin wet films of varnish on a wire, and baking or fusing the resin portions of each coating in an enamel oven. It is necessary to reach the desired coating build-up in a number of thin coats in order to eliminate entrapped solvents from the final film coating. This group is characterized by excellent space factor and flexibility, smooth appearance, high dielectric strength and often good moisture resistance. They are often used where space requirements are stringent and where special shaping of the coils is necessary. Shortcomings of the group are inability to withstand adverse winding conditions, lack of resistance to cut through, loss of dielectric strength upon cracking either from solvents, winding, baking, or aging, and failure to withstand environmental conditions.

▸ **Fibre covered types.** Produced by helically wrapping single or multi-layers of fibre or tape strips around the conductor, and using adhesives, bonding materials or varnishes to cement the materials in place. The insulation is of the spacing type and is exceptionally safe from overloading. Shortcomings of this group are lack of moisture and contamination barrier, poor space factor, poor coverage on sharp bends, lack of consolidation in multi-layer coils (may lead to poor heat transfer).

▸ **Film taped types.** Produced by helically wrapping one or more layers of plastic film tapes over the conductor. These films may or may not be bonded or heat-sealed. This insulation has higher dielectric strength than the fibre types, usually better resistance to cut through than the film types, better resistance to moisture and contamination than the fibrous types and good resistance to winding abuse. Shortcomings are poor space factor, poor flexibility and opening of tapes on sharp bends.

The activity in synthetic polymer chemistry in the past fifteen years has had a profound bearing on the magnet wire insulation field. Up to the 1930's the magnet wire industry had relied on a natural drying oil type of oleoresinous enamel for a coated insulation and natural fibres such as cotton and silk for wrapped insulations.

During the 1930's two new synthetic resins became available to the electrical industry namely, polyvinyl acetal or formval and polyamide or nylon. The historic adaption of these synthetics to magnet wire insulation revolutionized the electrical apparatus field. These new products had such superior mechanical properties that new high speed coil winding equipment could be utilized.



2. A bank of fine wire drawing machines in operation at the Canada Wire and Cable plant in Simcoe.

The success of formvar and nylon was so phenomenal that greater activity was stimulated in the synthetic resin field. This has led to the evaluation of most of the newer synthetics as magnet wire insulations. The difficulty here is that each appears to have a peculiar balance of advantages and disadvantages which makes it most suitable for certain applications. This has prevented the development of a truly universal magnet wire insulation.

In recent years the trend has concentrated in the field of higher operating temperatures. This need for higher temperature insulations has spurred the development work in inorganic and synthetic high polymer fields. Rather than review all the development work on the adaption of new organic and inorganic materials to magnet wire insulations, we will list a number of the newer types of magnet wire insulations available today.

Film coated types

Polyurethane
Pigmented polyurethane
Polyester
Epoxy
Silicone
Teflon
Teflon over ceramic
Ceramic
Anodized aluminum

Fibre covered

Cellulose acetate
Glass
Dacron and glass
Glass silicone
Mylar quinterra

Film taped

Teflon
Mylar

Because of the extreme complexity and variety of end applications for magnet wire, it is probably one of the most demanding fields in the electrical industry for the development and control of insulations and conductors.

The greatest areas of development in the future appear to be in high temperature applications. This has promoted a great deal of development work, both in the insulation and the conductor field. The results of this development work will be realized by the electrical industry by:

(1) Greater control in the selection and processing of raw materials into magnet wires.

(2) New and improved types of insulation and conductors, particularly in the field of high temperatures.

(3) New approaches to the functional testing of magnet wires and magnet wire insulations.

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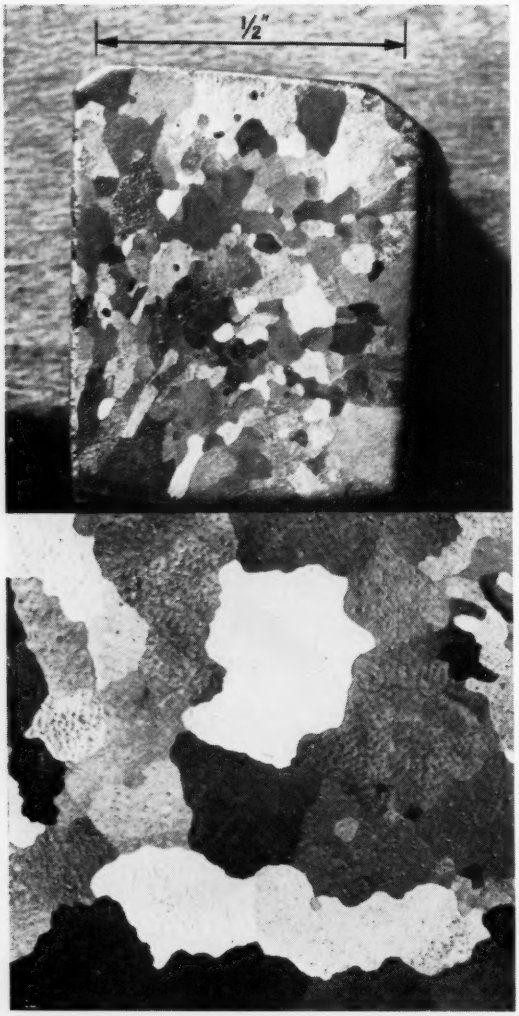
J. Allan

Initial design dictates final quality

In high conductivity copper castings for electrical applications



1. Macrographs of different sections of same casting. Variation in grain size result of section thicknesses.

There is little doubt that high-conductivity copper castings have valuable properties which make them highly desirable from the electrical engineer's viewpoint. The unique ability of the casting process to produce shapes not possible economically by other known methods, coupled with those properties which promote high electrical conductivity in a casting, provide the design engineer with a very potent and useful tool.

The early part of this report is devoted to the manufacture of castings in 99.99% purity electrolytic copper ingot and shows how casting design affects the quality of a cast part.

Effect of section thickness

High conductivity copper castings are highly section sensitive. Figure 1 shows macrographs of two different sections of the same casting made in high conductivity copper. The grain size of the section shown in the lower view is large and coarse, while the grain size shown in the top view is much smaller and finer. Test bars cut from a section such as shown in the former would produce much lower mechanical strengths than similar test bars cut from the section shown in the latter. The grain size in the lower view would have poorer hydraulic soundness than that section shown in the top view.

Irregular grain size and liquid shrinkage cavities due to section changes account for a high percentage of casting failures — especially failures on hydraulic test. Very often this shrinkage can be traced back to casting design or faulty foundry practice.

It may safely be said that shrinkage defects, coupled with gas unsoundness, account for over 90% of all failures of copper castings where they do not meet the required specifications.

Liquid or volumetric shrinkage unsoundness is caused by the failure of the gating and feeding system used in the foundry to replenish liquid, or volumetric shrinkage taking place from the pouring temperature of the molten metal to the solidus temperature. From 2,200 F to 1,800 F the volume of the poured mass will be reduced by approximately 6%. The feeding

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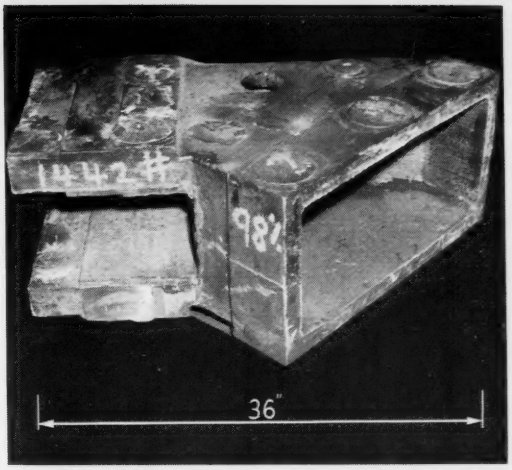
system used by the foundry must compensate for this volumetric reduction by providing feeding heads adjacent to areas of such reduction, because lighter sections of any given casting tend to "feed off" the adjacent heavier sections. In castings of simple design, "feeding heads" or "risers", as they are called in foundry terminology, can be placed either on or adjacent to local heavy sections to provide reservoirs of feed metal where required.

The ideal condition for soundness lies in promoting progressive solidification from the farthest point of the casting to the feeding heads on the casting. Castings of irregular sections must be designed with heavy sections connected to light sections in such a manner that the heavy sections cannot easily be "fed." A fed design will almost certainly lead to a casting which will contain rather serious shrinkage unsoundness which is likely to be revealed during the machining operation. Very often expensive welding or impregnation must be resorted to in order to salvage such a part.

Consultation with the foundry should alert the design engineer to the difficulties likely to arise from casting such a part and some redesign might considerably reduce the problems.



2. An indication of the size and complexity of castings possible with high-conductivity copper is illustrated.

Behavior of molten copper

Molten copper follows the behavior pattern of most molten metals. Rapid cooling from the molten state to room temperature promotes higher density, smaller grain size and higher mechanical strengths than slow cooling within the same metal section. When poured into a section two inches thick, copper reveals physical properties quite different from those of the same sample of metal poured into a section of smaller thickness provided pouring temperature and all other controllable conditions remain constant.

Basically, to obtain the soundest, highest strength per unit volume within a casting, castings should be designed to have the thinnest possible wall sections which will be able to be filled with molten metal and still meet the mechanical and physical requirements dictated by the end use of any given part. Rapid changes of section should be avoided.

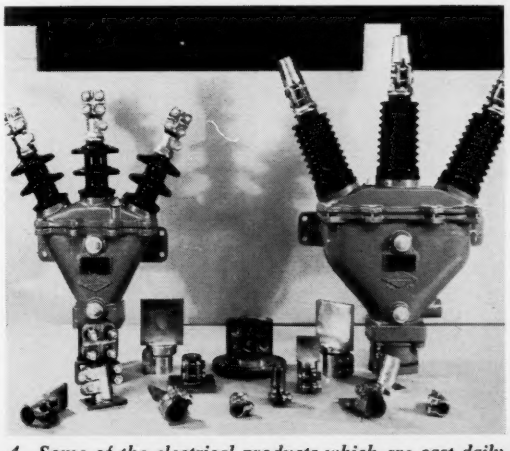
Observance of these simple requirements would do much to reduce complaints regarding faulty castings which lead to expensive failures, either in the machine shop or in service.

3. Electrode holder for furnace—weight over 2,000 lb.

Although this statement is broadly true of all cast metals, it is particularly true of cast high purity commercial copper and the failure of foundry operators to demonstrate to design engineers that high-quality copper castings can be produced satisfactorily, has led designers to overdesign current carrying parts, by forcing them to turn to alloys of low electrical worth, but easier to fabricate.

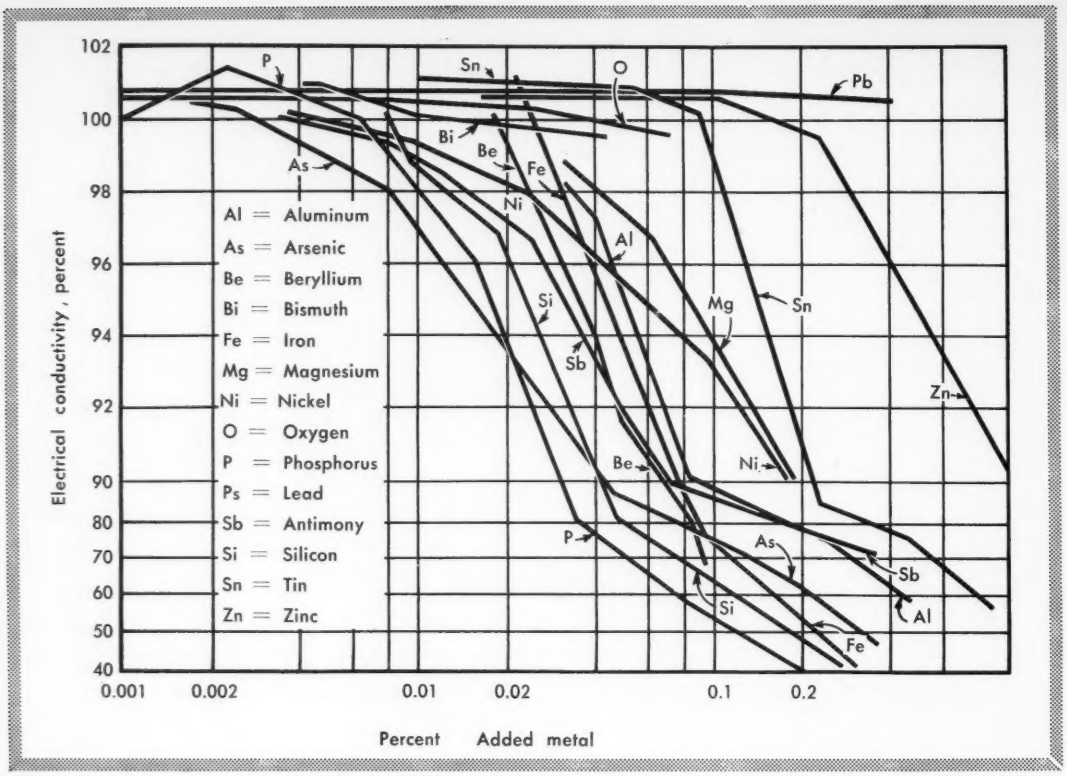
Difficulties of casting pure copper

As a result of having specialized in the manufacture of high-conductivity copper castings and forgings, the foundry where the author is employed has become a central check point for many users of "high conductivity copper castings". The quotation marks are used because in carrying out many checks, it has been only very occasionally that a cast part from an external source has been found to exceed 38% electrical conductivity when measured against the International Annealed Copper Standard.



4. Some of the electrical products which are cast daily.

continued



5. Graph of the effect on the small percentages of elements entering into solid solution with copper—note how the conductivity drops off quickly for most of the added metals.

In light of the special techniques involved in making high conductivity copper castings and forgings, these results are not at all surprising and the graph shown in fig 5 gives the effect of some of the common elements when they are alloyed with copper. It will be noted that almost all of these elements have a very serious deleterious effect on the electrical conductivity of copper even when present in very small amounts.

Molten copper has a very high affinity for oxygen and hydrogen, an affinity which increases with increase in temperature. As a result it is often felt to be desirable in the foundry that some element with a higher affinity for oxygen be added to the copper in order to improve its castability.

This is very sound foundry practice and such elements very often do improve the castability but a glance at the graph shows that such elements will lower the electrical conductivity of pure copper to below 40% very rapidly so that, of course, the resultant alloy will no longer be high-conductivity copper. This explains why many so-called high-conductivity copper castings heat up in electrical service even though they look to be high-conductivity copper.

Copper and alloys of copper

Many attempts have been made to form alloys of copper, which in the "as cast" state would give high electrical conductivities and good mechanical strengths coupled with good machinability. The best of these "as cast" alloys produce electrical conductivities of the order of some 40% to 45% and Table 1 shows typical mechanical properties of one such alloy together with its composition.

If properly processed within the foundry, so that contamination is completely avoided, electrical conductivities of not less than 90% IACS can be guaranteed in pure copper. Electrical conductivities of 96% or 97% are quite usual under good conditions and very shortly the author's company expects to be able to guarantee minimum conductivities of 95% IACS in copper castings. (Forgings made from hi-con copper properly processed often produce electrical conductivities 101% IACS.)

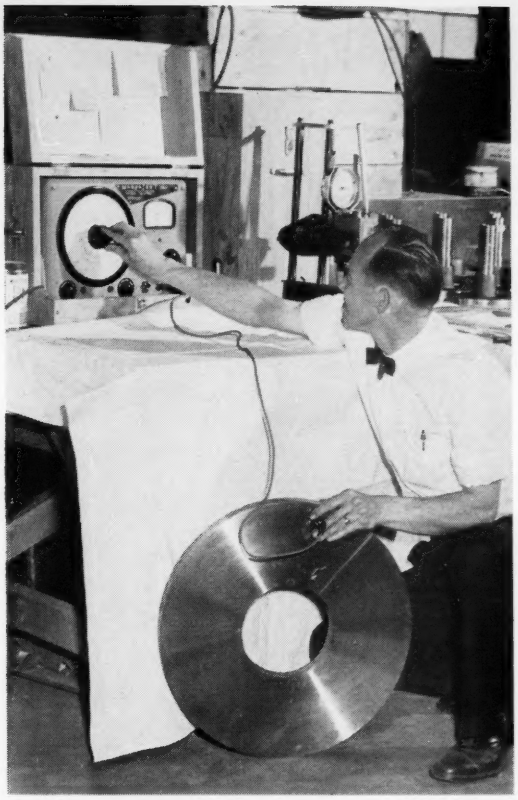
In order that much higher mechanical strengths, coupled with very good electrical conductivity might be obtained, a new group of alloys which are susceptible to solution annealing and precipitation hardening have become available.

Casting size

Speaking still of 99.99% commercial copper, there is no limit in size or weight to the practical production of any casting in high-conductivity copper other than that of the capacity of the foundry undertaking the work. Fig 3 shows an electrode holder for a steel furnace, the casting for which weighed over 2,000 pounds before machining.

Machining pure copper

The general difficulty of machining pure copper castings as compared to machining alloys of copper,



6. Magnatest conductivity meter, type FM-100, utilizes principle of eddy currents—used on copper casting.

has caused machine shop operators to enlist the aid of electrical design engineers in not specifying high-conductivity copper.

High-conductivity copper does not lend itself to high-speed machining but the difficulties of machining have been grossly exaggerated. It is possible to satisfactorily machine copper castings to a very high finish, and some experience in machining such castings has provided the following useful information.

Carbide-tipped tools have not been found to be too successful in machining copper but high-speed tool bits ground to give all possible clearance at all points of contact with the casting, have proved to be quite successful.

Forecasting quality

Although a part is simple in shape, the water passages which crisscross through the centre section pose a serious challenge to the foundry undertaking the work. As stated earlier in the paper and shown in figure 1, high-conductivity copper is highly section sensitive and this means that the longer a casting takes to cool from pouring temperature to the solidus temperature, the greater the grain size and the greater the risk of internal shrinkage porosity. Fig 7 shows diagrammatically how molten copper solidifies; the sharp columnar crystals form in the areas of fastest cooling which are always on the inner and outer surfaces of the casting. The crystals increase in size as

Table 1

Medium conductivity alloy

Nominal Chemical Composition

	Typical	Preferred
Copper	94.5 to 96.5	95
Tin	0.5 max	0.5
Lead	1.30 - 1.75	1.5
Iron	0.03 max.	none
Zinc	2 - 3.5	3.0

Nominal Physical Properties

Tensile strength psi	32000-35000
Yield strength psi	10000-12000
% Elongation in 2 in.	25-42%
Brinell hardness	37-48
Electrical conductivity IACS	40-45%

Table 2

Electrolytic copper castings

Nominal Chemical Composition

Copper ..... 99.90% (Min.)

Nominal Physical Properties

Tensile strength, psi	25,000
Yield strength, psi	6,000
Elongation, % in 2 in.	55
Reduction in area, %	65
Brinell hardness (500 KG)	35
Electrical conductivity, % IACS .	90 (Min.)
Weight, lbs. per cu. in.	.320
Thermal conductivity, BTU/sq. ft./ft./hr./°F	2.25
Specific gravity	8.87
Modulus of elasticity, psi	17,000,000
Coefficient of thermal expansion, in./in./°F	.0000098
Yield in compression, psi (.2% offset)	4,000

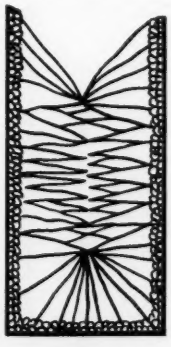


Figure 7

continued ▶

cooling time increases, a condition which is always aggravated toward the centre of any cast section and is somewhat proportional to section size.

From this description, it becomes obvious that those parts of **any** casting which are least likely to leak are the outer and inner surfaces of a casting. This very simple fact immediately highlights the paradox that the tight dense homogeneous areas of any casting **are the parts that are removed by machining** in readying the part for its end use.

Here then is the simple phenomenon which explains over 70% of all failures on pressure test. Here then is why there is no such thing as a casting which can be guaranteed not to leak because there are no known tests which will predict that a casting won't leak. There are several tests such as radiographic inspection and magnaflux testing which might predict that the casting will leak but there are none to predict that it will not leak.

Failure to accept this simple phenomenon embodied within the cast process — the solidification phenomenon — has caused more heart burning in foundry circles over leaky castings than any other single cause.

Although there are several tricks used to promote denseness and soundness in castings, these are outside the scope of this article. In any case, all of the talk, all of the criticism, all of the words of the wise, cannot alter this condition and if this condition cannot be compensated for in the design, coupled with good foundry practice, then another method of manufacture must be found.

Electrical conductivity

In answer to the question constantly asked whether or not it is possible to "guarantee" high electrical conductivities in castings, the answer is an emphatic "yes".

It is usually ignorance of the techniques or failure to impose sufficiently rigid controls which cause many foundries to give up on the manufacture of high-conductivity copper castings.

Obviously, anything can be **guaranteed** only if it can be tested to the point of the guarantee.

The standard ASTM procedure for checking electrical conductivities is covered by ASTM B-193-49 and is somewhat protracted and rather costly. Briefly, this test consists of preparing by machining a specimen of exact dimensions and rigging this specimen in an apparatus which will measure its resistance and this resistance is translated in terms of conductivity.

This procedure, while excellent for laboratory testing where accuracy is the keynote, is much too slow to be used in the production checking of castings and forgings which must be cast with high electrical conductivities. It is surely sound practice to have any test which might scrap a part made as early in the production process as possible and if many castings have been produced and are awaiting laboratory conductivity checks, the risk could be disproportionately high in relation to the total value of the work involved.

St. Catharines Brass Works Limited is among the very limited number of foundries which employs high-speed testing for electrical conductivity. This test is done on a Magnatest unit as shown in fig 6.

The Magnatest Conductivity Meter, type FM-100, is an electronic testing instrument which utilizes the principle of eddy currents to measure the electrical conductivity of **non-magnetic** metals and alloys. It will also give an indirect measurement of properties which are directly related to conductivity such as age or precipitation hardening of aluminum alloys.

Engineering liaison needed

With suitable liaison between electrical engineering designers and highly qualified technical foundry personnel, copper castings with good hydraulic soundness and high electrical conductivities can be made satisfactorily.

The casting process has very definite limitations, seriously affected by any given design, so forging must always be considered when a casting is unlikely to fill the need.

Where copper is not hard enough or strong enough for any given requirement, the Mallory metals of chromium copper, beryllium copper and cobalt nickel copper are readily available.

There is no need to settle for less than the best by using alloys of low electrical conductivity in place of alloys of high electrical conductivity because good techniques in the hands of an expert can produce excellent results in terms of excellent high-conductivity copper parts. ★

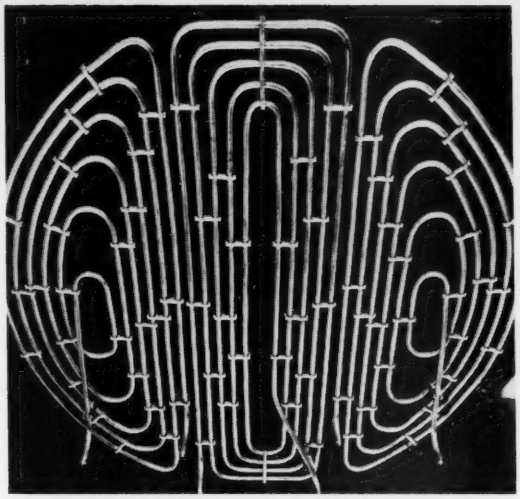
Coming next month . . .

exciting news for design engineers

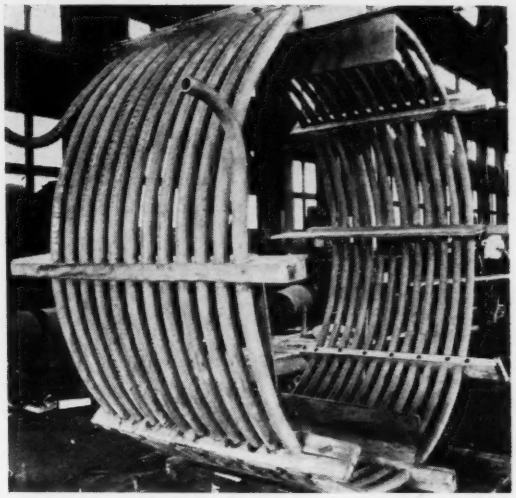
Articles in the April issue will include a feature discussion on jig boring . . . how to design for bolt bending stresses . . . the design philosophy of the Austin seven . . . part 2 of our series on Bourdon tubes . . . and a challenge to would-be managers.

Read what the experts say in next month's

Design Engineering



1. Ease of fabrication makes possible intricate layouts.



2. Large cupralum heating and cooling coil for brewery.

For handling corrosives — it's copper

Lead clad copper pipe and tubing is ductile, rigid, self-supporting

G. N. Thomas

Exclusive DE Feature

Cupralum is copper, or high copper alloy of selected type and thickness, to which a uniform dense-structured, nonporous, extruded chemical lead cladding has been inseparably applied. The outside lead covering and the interior copper tubing are metallurgically bonded together.

Production of cupralum is carried out by a patented process. All sizes of copper tubing or copper pipe may be lead clad. It is practical also to manufacture lead lined copper tubing and pipe. In addition, this process is employed to lead clad pipe and tubing fabricated from a variety of other metals and alloys. Lead clad rods, bars and strip of various compositions also are produced.

It should be borne in mind that, wherever a metal shape, angle, channel, form or object has a straight through cross section, it may be lead clad, within certain size limitations.

Use with corrosive liquors

Where these products are employed with corrosive liquors, it is recommended that the lead cladding never be less than ⅛ in. thick. It is practical to apply coverings or linings in any lead thickness desired; standard thicknesses for use with corrosive liquors in common employment are ⅛, 3/16, ¼, ⅜ and ½ inch.

Mr. Thomas, author of this article is with the engineering department of Canadian Vickers Ltd., Montreal Que.

The quality of cupralum produced by the extrusion process should not be confused with products resulting from casting in molds, or hand application of lead. The extrusion process assures:

(a) A metallurgical bond without the employment of tin between the lead covering and the copper tubing. Tin is definitely objectionable because it may contaminate the lead covering, and impair corrosion resistance. Tin has a much lower melting temperature than the lead covering or the copper tubing, and its presence lowers the temperature at which the product may be employed.

(b) A dense, tight extruded lead grain structure, free of pinholes, porosity, laminations, etc.

(c) A uniform thickness lead cladding, so that no areas are improperly protected.

(d) Excellent quality control, because all operations are by machine methods and controls. Production steps are of an exposed nature, which is of important benefit during inspection.

Use with acids

Lead is the favorite medium for use with H_2SO_4 in all its ramifications. It resists all concentrations of sulphuric acid up to 85% at temperatures to 428F. Where

continued ▶57

concentrations of sulphuric acid up to 85% are encountered at temperatures over 428F, and up to about 482F, lead also possesses very good life compared with other metals or alloys. Lead commonly is used with phospheric acid, chromic acid, sulphites, sulphates, alum and the like. There are many additional acids, too numerous to list, for which lead possesses excellent corrosion resistance. If lead has given unsatisfactory service in the past with a given acid, this probably was due to physical limitations which might not be present in cupralum.

Heat transfer considerations

Copper absorbs and transfers heat with the greatest efficiency, and, because the lead is metallurgically bonded to the copper, heat transfer is kept at a high value. Because the physical strength to withstand high steam pressure is provided by the copper, it is practical to keep the heat transfer efficiency of cupralum is superior to

Thus, the combined thickness of copper and lead is materially less than the wall thickness of lead pipe. Also, the heat transfer efficiency of cupralum is superior to that of the hard metals.

Heat Transfer Value

CUPRALUM TUBING FORMULA: for calculating theoretical over-all rate of heat transfer coefficient "U" in Btu/hr/sq ft/ deg F.

$$U = \frac{1}{\frac{X}{K} + \frac{1}{h_1} + \frac{1}{h_2} + \frac{Y}{K_1}}$$

Where:

K = Conductivity of lead wall per inch — Use 240
K_1 = Conductivity of copper wall per inch — Use 2680
X = Thickness of lead wall in inches
Y = Thickness of copper wall in inches
h_1 = Steam film — Use 1000
h_2 = Liquid film — Use 300

Example

1¼ O.D. C No. 15 ga. copper tubing with ⅛ lead cladding.

3. Copper anodes (background) used in chrome-plating.

$$U = \frac{1}{\frac{.125}{240} + \frac{1}{300} + \frac{1}{1000} + \frac{.072}{2680}} = 206 \text{ BTU/hr/sq ft/°F}$$

The actual heat transfer rate of all metals is affected by the formation of interior and exterior corrosion scale on the tube surfaces. This must be considered in determining the square footage of heating surface required. Depending on the frequency with which coils are cleaned, and the nature of the corrosion, heat transfer rate in practice may be as much as 20% under calculated rates.

FORMULA FOR CALCULATING HEATING SURFACE OF CUPRALUM COILS:

H = Total heat lead, BTU per hour
U = Over-all rate of heat transfer in BTU/hr/sq ft/°F. (See formula above)
T = Mean temperature difference between the hot and cold liquids, in °F.

For heating coils:

$$\text{Steam temp. °F} = \frac{\text{Starting} + \text{final temp. of solution}}{2}$$

$$\text{Heating surface area} = \frac{H}{U \times T} \text{ (sq ft)}$$

Coil design

Information required to design coils:

1) Quantity of solution to be heated or cooled in gallons
2) Specific gravity
3) Starting temperature
4) Final temperature
5) Time cycle desired, or necessary, to process
6) Maximum available steam pressure (for cooling, state temperature of cooling medium)
7) Sketch of tank or vessel in which process is carried out.

The well-known physical properties of copper are the factors which represent the physical limits of cupralum. Copper possesses strength, ductility, weldability, and high fatigue resistance. Because the lead is metallurgically bonded to the copper, it expands and contracts with the copper during temperature changes. In the absence of a bond, lead expands more than it contracts, resulting in fatigue failure of the lead.

Cupralum tubing

Cupralum tubing, while ductile, is rigid and self-supporting. There is no distortion or collapse of the coils when designed with simple legs or frames. When bending, it is found that the lead cladding improves on the good bending qualities of the copper tubing, in that it supports the copper tubing and prevents flattening. Cupralum coils withstand repeated shock, vibration, sharp temperature changes, and may be cleaned periodically. They are lighter in weight, much stronger than lead coils, easy to handle, and may be employed with temperatures up to a maximum of 500F, based on consideration of all factors. These include, corrosion resistance, physical properties, steam pressures, temperature cycles, etc. Cupralum tubing is recommended for steam pressures up to 150 psi based on the following wall thicknesses of copper tubing:

continued page 60 ▶

COMPACT, RELIABLE, VERSATILE . . .

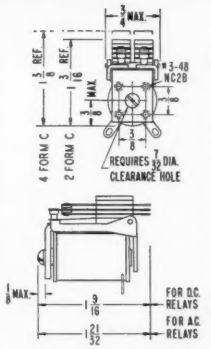
this is P&B's miniature MH relay

The MH is not a new relay.

As a matter of fact, we've been building and selling this series for seven or eight years. Its reliability and exceptional longevity have been proved in business machines, airborne computers and a host of other products.

Engineers like its fast action, its small size, its light weight. They like the wide selection of contact forms . . . up to 18 springs (9 per stack, DC) as well as the fact MH relays can be furnished to switch loads ranging from dry circuit to over 5 amps at 115 volts, 60 cycle resistive.

A multiple choice of terminations add to the MH's versatility. This relay, for example, can be adapted for printed circuits, furnished with taper tabs or a long list of other terminals. Get all the facts by calling your nearest P&B sales engineer today.



MH ENGINEERING DATA

GENERAL:

Breakdown Voltage: 500 volts RMS between all elements.

Ambient Temperatures: −45° C to +85° C. (−65° C to +125° C on special order.)

Shock: 30g on special order.

Vibration: 10g from 55 to 500 cps., .065" max. excursions from 10 to 55 cps. on special order.

Weight: 2½ ozs. max. (open relay)

Terminals: Pierced solder lugs; special lugs for printed circuits, taper tab (AMP #78).

CONTACTS:

Arrangements: Up to 9 springs per stack.

Material: ⅛" silver standard: Palladium or gold alloy also available.

Load: Dry circuits to 5 amps @ 115V AC res.

COILS:

Resistance: 22,000 ohms max.

Power: 100 mw per movable min. to 4 watts at 25° C max. (200 mw min. to meet max. shock/vibration spec.)

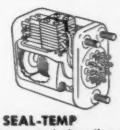
Duty: DC: Continuous. AC: Intermittent (Two pole relay max.) open. Sealed units supplied with full wave rectifier inside can.

Voltages: DC: Up to 110 volts. AC: Up to 230 volts 60 cycles.

The relays below are variations of the MH relay structure.

MA LATCHING
Electrical latch, mechanical reset. Small, versatile and offered with selection of contact arrangements.

MB CONTACTOR
Contacts rated 60 amp. 28 volts DC non-inductive. Will carry 150 amp. surge for a duration of 0.3 seconds.



MH SEAL-TEMP
Features sealed coil to minimize contact contamination. Available as hermetically sealed relay only.

P&B STANDARD RELAYS ARE AVAILABLE AT YOUR LOCAL ELECTRONIC PARTS DISTRIBUTOR

POTTER & BRUMFIELD CANADA LTD.

GUELPH, ONTARIO

For further information mark No. 141 on Readers' Service Card

1 in. —16 gauge	1¼ in.—15 gauge
1½ in.—14 gauge	2 in. —14 gauge

When higher steam pressures are encountered, heavier thicknesses of copper may be employed.

Cupralum tubing may also be purchased preformed to the diameter and spacing of the coil required, and field mechanics may finish the equipment by applying suitable coil-legs.

It is possible to prolong the life of cupralum coils by repairing the lead cladding, should it ever require such attention. Since the strength of the coil is provided by its copper tubing core, it is only necessary to preserve the lead cladding to extend the life of the coil. This is done by scraping the clad surface in need of repair, and re-applying additional lead by melting on burning bar through ordinary lead burning techniques. Periodic inspection during shut-downs is recommended.

Legs, frames and hangers for cupralum coils are fabricated from ferrolum (lead clad steel) in a variety of forms, depending on diameter, shape and weight of the coil. Steel is relied on to provide the rigidity and strength important to good coil construction, and the metallurgically bonded lead cladding of steel in ferrolum protects it from corrosion. Solid lead legs may be used but these are costly, add undesirable weight and provide no real strength, since the lead legs distort under temperature cycling.

Standard sizes recommended

Standard diameters of copper tubing from ¼ up to and including 2 in. are considered standard sizes of pipe for lead cladding. Larger diameters also may be lead clad as non-standard items.

Standard thicknesses of lead cladding are: 3/32, ⅛, 3/16, ¼, ⅜ and ½ in. Intermediate or heavier thicknesses are produced as non-standard coverings. For those who wish to fabricate their own coils, the following is pertinent.

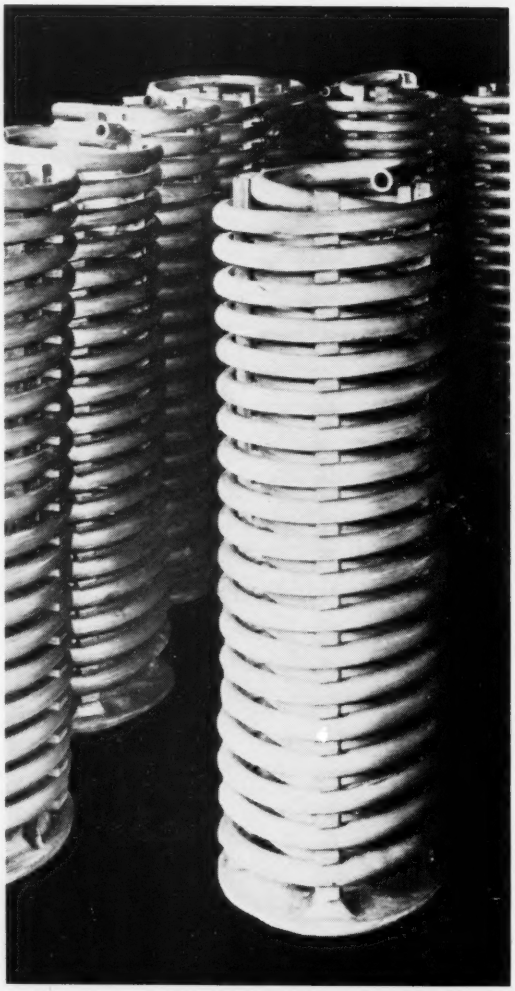
Cupralum tubing is produced in twenty foot lengths or in long continuous coils, similar to lead pipe. Coil lengths are from forty feet to one hundred feet, depending on the diameter of the tubing. Where joints are necessary, the flare type joint is employed, and the copper tubing silver-soldered. Joints are put under pressure test prior to lead cladding. The lead covering of the copper joint may be mold-made or applied by lead burning.

Anodes fabricated from cupralum are doing an outstanding job where difficult chrome plating problems are encountered, and, in several instances, have made hard chrome plating processes practical which were previously impractical. Where bores are hard chrome plated, where over-all length of objects being plated is great, or where the work has irregularities or recesses, cupralum anodes are ideal. They possess approximately ten times the current carrying capacity of ordinary lead anodes, and, since the lead cladding in cupralum is metallurgically bonded to the copper core, there is no loss of current during transmission. The lead of cupralum may be chemical lead, antimonial lead, or 7% tin lead. Where a silver content lead is preferred, it can be supplied. In addition to conventional flat anodes, cupralum is manufactured in the form of bus bars, rods, wire, or as basket type anodes. Cupralum anodes are stiff and strong, but should nevertheless be subjected to careful maintenance, because they are used for the most severe plating conditions. Also, since they can be easily repaired, it is desirable to extend their life to protect the copper cores from exposure to the electrolyte.

Cupralum as a shield in atomic equipment

It should be remembered that cupralum also combines the gamma shielding properties of lead with all the desirable fabricating characteristics of copper and copper alloys. Therefore, when it becomes necessary that gamma shields of atomic machinery and equipment have built-in cooling systems, cupralum can be relied on to combine the heat transfer value of copper with the shielding value of lead.

Sometimes it is necessary to transport radioactive liquors and spent resin discharge from demineralizers into processing vessels for concentrating radioactive solutions. The conduct of these solutions requires red brass with a very heavy outside lead cladding. The red brass interior of cupralum has the ability to resist the corrosive solutions, and of course, the outside lead cladding of cupralum resists the escape of gamma radiation. ★



4. Tightly wound centre-spiral coils are readily formed.

...and that name is "FILTORS"

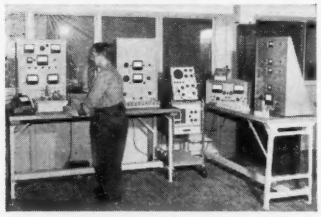
Hermetically Sealed Sub and Micro-Miniature Relays

DESIGN and CONSTRUCTION

"Filtors" Sub-Miniature and Micro-Miniature Relays meet or exceed all the requirements of MIL.R 5757C. Lightweight and rugged, they are hermetically sealed and uniquely designed to provide immunity to the forces of shock, vibration, acceleration, as well as high tolerance to extreme environmental conditions of pressure and temperature.

COMPLETE RANGE

"Filtors" Sub-Miniature and Micro-Miniature (Hermetically Sealed) Relays are available for both AC and DC operations. Non-standard terminal arrangements can be designed to meet special requirements.

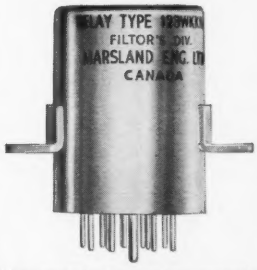


ENVIRONMENTALLY TESTED IN MANUFACTURE

"Filtors" designs lend themselves to exacting standards of inspection. At Marsland Engineering the Filtors Relay Division is air-filtered, temperature controlled and surgically clean. Fine materials and the quality controls employed by Marsland result in Relays built to the most reliable standards available anywhere.

Manufactured and sold in Canada under license from Filtors Incorporated, Port Washington, Long Island, by "FILTORS" Relay Divison of

The "Powrmite" crystal case performance package for all micro-miniature relay switching requirements. Available for plug-in or fixed-wire mounting.



These general purpose relays are applicable to instrument, geophysical, aircraft controls and circuits where high reliability, multiple switching is required. In 2, 4 and 6 pole double throw contact arrangements with many standard mountings.

MARSLAND ENGINEERING LIMITED

KITCHENER, ONTARIO

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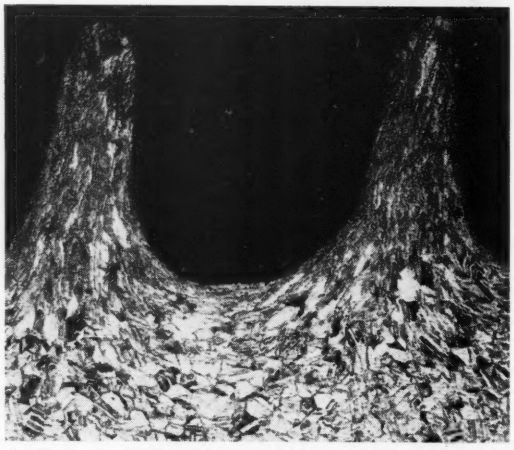
Selection of tube elements for heat exchangers

Low-finned copper tube is as handy to use as bare tube

G. T. Fenwick, P.Eng. and R. B. Stotts



1. Two views of section of tubing. Upper—before finning; lower—after. Note distortion of grain structure.

Until nine or ten years ago, the basic heat transfer element for the process industries was bare condenser tube. Today, with the increasing usage of integral low-finned tube, we can now consider two basic heat transfer elements available for shell and tube exchangers, namely low-finned tube and bare condenser tube.

For any given set of conditions one of these elements will have first cost advantages over the other, which will be determined by such factors as the type of process, the heat transfer characteristics of the process stream, allowable pressure drops, fouling margins desired, and materials of construction.

Low-finned tube

Low-finned tube is as easy to use as bare tube in conventional shell and tube heat exchangers. The fins are radially extruded from thick-walled tube to a height of 1/16 in., producing a smooth fin contour without any sharp angles or crevices. The tube is designed so that the outside diameter of the fins is slightly less than the base tube. By omitting the fins at the ends, the tube may be inserted into a conventional tube bundle and rolled into the tube sheet in the usual manner.

The heavier wall thickness of the plain end section of the low-finned tube provides extra strength at the tube sheet where stresses in service tend to concentrate. Although the fins actually increase the bursting strength of low-finned tube, the design limitations on working pressures as specified in the ASME code for Unfired Pressure Vessels are determined from the minimum wall thickness under the fins.

Copper and copper base alloy plain tube that is used in the manufacture of finned tube is produced by the hot extrusion, cold drawing process, and is usually manufactured to either ASTM B-75, covering seamless copper tube suitable for general engineering purposes, or ASTM B-111, which covers seamless copper and copper alloy tube, for use in surface condensers, evaporators and heat exchangers. The temper of the plain tube is used for low-fin is normally annealed with a grain size of .040 to .080 mm at 75X. The physical tests required by these specifications can be performed on the plain tube prior to finning, or on the plain ends after finning.

Because finning consists of rolling and extruding the fins from the original tube wall, this operation in itself is therefore a very severe test of tube quality. Any surface imperfections or internal flaws in the plain tube, resulting from the casting, extrusion or drawing operations would most probably result in failure of the tube during the finning operation.

Because of the severe cold working of the tube in finning and of the susceptibility to stress corrosion cracking, all admiralty and aluminum finned tube is stress relief annealed, unless specified as fully annealed for bending.

Fig 1 shows a longitudinal section of a Type B Admiralty plain tube ready for finning, and a longi-

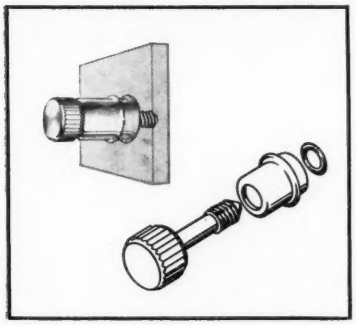
Mr. Fenwick is production manager of Unifin Tube Company and Mr. Stotts is quality supervisor of Wolverine Tube Division of Calumet and Hecla of Canada Limited, London, Ont.

continued page 64

Compact Captive Panel Screws:

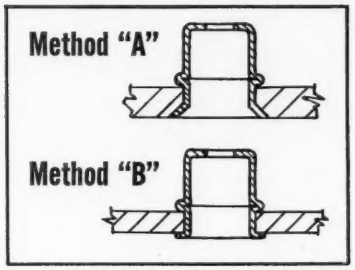
Standard Design Lowers Installed Costs

No longer is it necessary to resort to a costly fastening device of special design to provide quick attachment and release of electronic components. Standard Southco Retractable Screw Fasteners (stand-off thumb screws), available from stock, are both fast to install and economical. The five sizes,

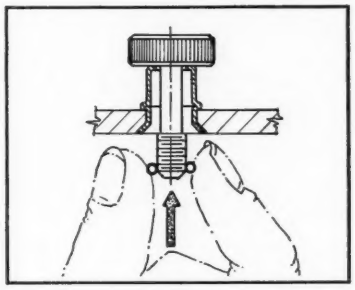


shown below, meet a very wide variety of requirements.

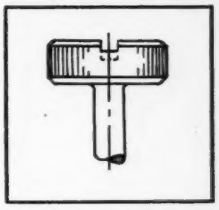
Check these advantages of simplified Southco Captive Panel Screws. Even when many screws are in one panel, misalignment is easily handled because the screw floats in a large hole in the stand-off, allowing ample play for "lining up." No special tools are



needed for installation, thus production is not subject to tool failure, nor limited by either the number of special tools available or the number of personnel trained in their use.



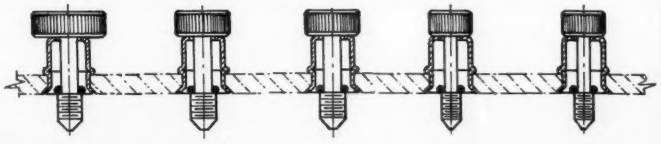
The Southco No. 58 Retractable Screw Fastener consists of three parts: thumb screw, stand-off, and retaining ring. The bright nickel-plated brass stand-off is inserted in either a drilled and countersunk hole (Method A), or a drilled hole (Method B), and flared. The polished, chrome-finished brass screw is passed through the hole in the stand-off and made captive by a retaining ring. Engaging in a tapped hole



in the frame, the screw may be fully withdrawn without moving the panel, yet always is retained.

The unslotted screw is standard in $\frac{3}{4}$", $\frac{9}{16}$", and $\frac{7}{16}$" head diameters and three thread sizes. Slotted head screws are also available in all sizes. The stand-off is standard in sizes to fit panel thicknesses from a minimum of $\frac{1}{16}$" to a maximum of $\frac{17}{64}$". Screw and stand-off are also obtainable in stainless steel.

MINIATURE TO LARGE SIZE HEADS IN FIVE TYPES



HEAD DIAMETER	3/4"	9/16"	9/16"	7/16"	7/16"
THREAD SIZE	1/4-20	1/4-20	12-24	10-24	10-32

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tudinal section of the same tube after finning. Note the distortion of the grain structure showing the flow of metal in the finning process.

Differences in tube geometry

When comparing applications of low-finned and bare tubing it is necessary to consider the differences in tube geometry. The low-finned tube will have approximately 2½ times the outside surface area of a bare tube of the same nominal outside diameter. This results in an outside to inside surface area ratio of about 3.5 to 1 as compared with about 1.2 to 1 for a bare tube.

As the fin diameter is slightly less than the nominal tube diameter, the root diameter of the low-finned tube is ⅛ in. less, providing a greater effective clearance between tubes than bare tube on the same pitch. To provide the same shell side cross flow area as compared with bare tubes requires a smaller baffle spacing or a closer tube spacing. The inside diameter of the low-finned tube will also be ⅛ in. less than an equivalent bare tube. This will result in higher tube side velocity and pressure drop, with increased heat transfer coefficient for the low-finned tube. To provide equal tube side pressure drop requires a reduction in the number of tube passes for low-finned tube.

Bare condenser tube will generally be used in applications where the controlling combined film coefficient and dirt factor are on the tube side or when the inside and outside coefficient are of similar magnitude. Low-finned tube, on the other hand, will be advantageous whenever the dirtier fluid is on the shell side, or when the tube side coefficient is high.

Severe service considerations

It has been established that finned tubing can successfully operate in severe fouling services because normal deposits never occlude the fins, and hard brittle deposits will flake off low-finned tubes more readily than bare tubes. When a soft sludge-type deposit occurs, low-finned tube will be affected less than bare tube because the excess fin surface available for fouling results in a lower heat flux and smaller temperature drop through a given film thickness. In addition, the larger effective clearance between low-finned tubes will permit a greater dirt build-up before plugging occurs. These factors contribute to a longer cycle of operation for low-finned tube before cleaning becomes necessary, resulting in less downtime and reduced maintenance. Thus the fluid possessing the larger combined heat transfer and fouling resistance should be placed on the shell side to realize the advantages of extra fin surface of low-finned tube.

It is customary in commercial design to use the outside surface as the reference surface. When using bare tube the inside dirt factor is often used without correction for the difference in surface as the error is usually negligible. However, when using low-finned tubing the tube side dirt factor must always be multiplied by the ratio of outside to inside surfaces. As this ratio is about 3½ to 1, it can readily be noted that inside fouling factors are much more critical on low-finned tube than bare tube.

To compare heat transfer characteristics of bare tube and low-finned tube, consider first the basic heat transfer equation.

Heat transferred = Over-all coefficient of heat transfer × Total outside surface area × Temperature difference

$$H = U_o \times A_o \times \Delta T$$

The over-all coefficients of heat transfer are derived by combining the individual film coefficients and fouling factors all referred to the outside surface.

Over-all coefficient = Outside coeffic. + Outside fouling + Metal resistance + Inside coeffic. + Inside fouling

For bare tube
$$\frac{1}{U_o} = \left[\frac{1}{h_o} + r_{do}\right] + rm + \left[\frac{1}{h_i} + r_{di}\right]\left(\frac{A_o}{A_i}\right)$$

For low-finned tube
$$\frac{1}{U_o} = \frac{\left[\frac{1}{h_o} + r_{do}\right]}{E_w} + rm + \left[\frac{1}{h_i} + r_{di}\right]\left(\frac{A_o}{A_i}\right)$$

The only difference in the two equations is the factor E_w, called weighted fin efficiency. This factor is used

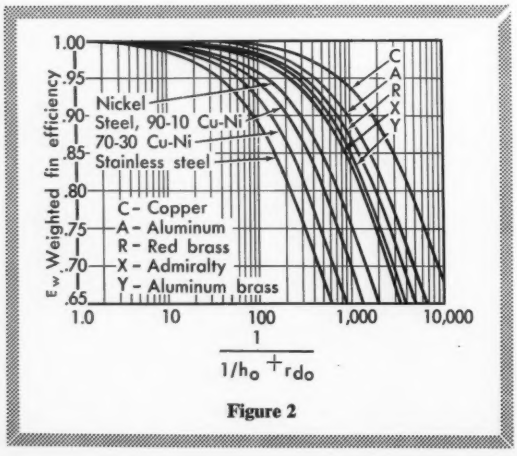


Figure 2

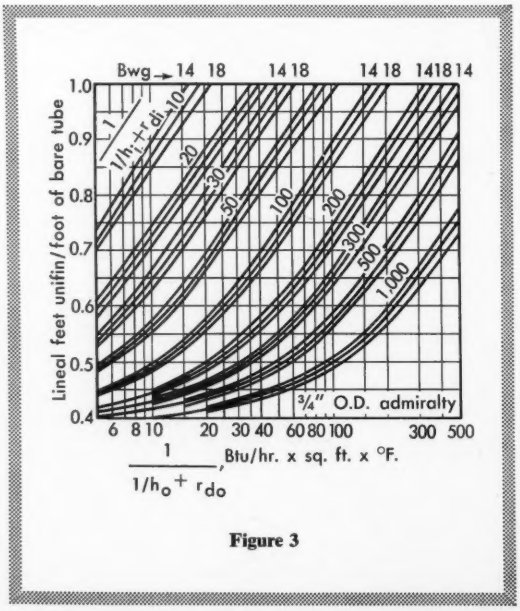
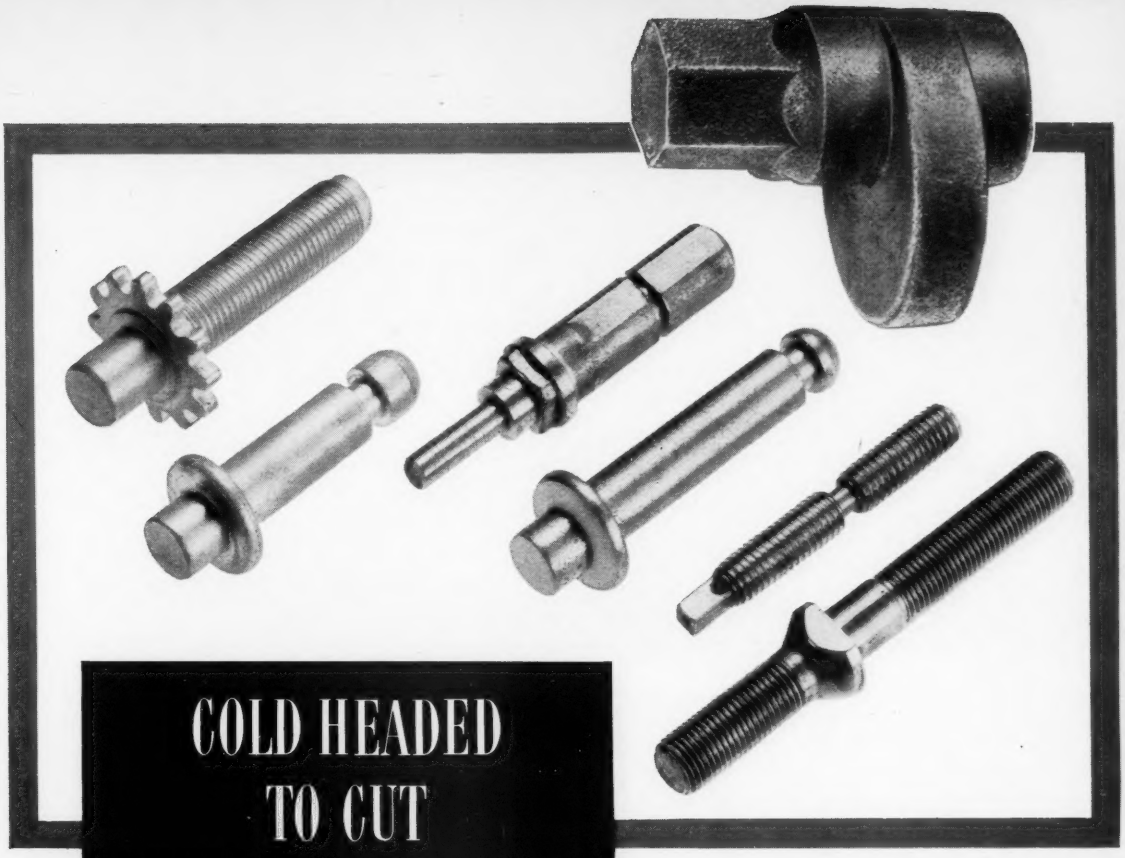


Figure 3

continued page 66



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to compensate for the fact that the temperature of the fins will be slightly less than the temperature of the base tube. The difference varies with the conductivity of the metal. The weighted fin efficiencies for various metal and alloy low-finned tubes manufacturer by the Unifin Tube Company are given in fig 2.

The inside coefficients for bare tube and low-finned tube are calculated in the same manner by conventional methods. The outside coefficient in forced convection for the low-finned tube bundle will be approximately 15% lower than for the same diameter bare tube, with the same tube pitch and shell side mass flow velocity. This is due to the larger equivalent diameter for the low-finned tube used in the heat transfer correlation. In design this may be adjusted by using a smaller tube pitch for the low-finned tubes. The only correction necessary for low-finned tube, which is not included in available correlations is to reduce the outside coefficient by a linear amount up to 30% for shell sizes from 15¼-in. to 8-in. inside diameter.

Some design considerations

A comparison of lineal feet of low-finned tube required per foot of bare tube is shown in fig 3, illustrating the effect of various combined film coefficients and dirt factors. This method presumes equal outside coefficients and includes the correction for fin efficiency, metal resistance and different surface ratios.

The choice between the two basic heat transfer elements in new exchangers is usually based on the final cost of the completed exchanger. Typical cost ratios of a low-fin exchanger as a percentage of one using bare tube with the same surface area, is shown in fig 5.

Low-finned tube has also found wide application in retubing existing equipment to obtain increased capacity.

Whether in retubing applications or new fabrication, low-finned tubing should be considered as one of the basic heat transfer elements for shell and tube exchangers. The final choice between the two types of tubing will be based on factors such as first cost, maintenance, and operating characteristics. The element best suited for any given set of process conditions may be readily determined. ★

4. Shell and tube heat exchangers on assembly floor.

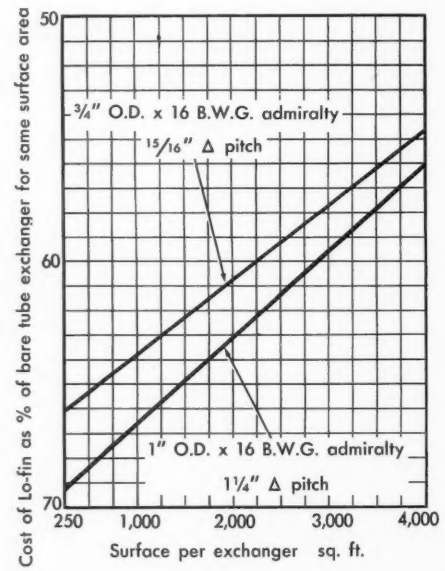
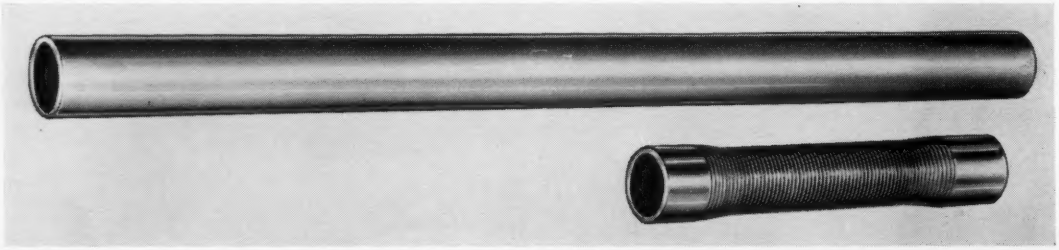


Figure 5



6. The long and short of heat exchanger design — plain and finned tubes have equal heat transfer properties.

People in the news

Avery

Timm

Burton A. Avery, P.Eng., has been appointed vice-president and assistant general manager of Orenda Engines Ltd. A design engineer, he was previously the company's chief engineer.

★ ★ ★

New consultant to join Orr Associates, Ltd., of Toronto, is furniture designer **Jan Kuypers.** Trained at the Academy of Arts and Architecture, The Hague, Holland, he came to Canada in 1951 and his designs are now internationally known.

★ ★ ★

An electrical engineering graduate of McGill University has become director of engineering for Dominion Rubber Co., Ltd. He is **C. Ritchie Timm,** P.Eng., who joined the company in 1940 as assistant to the director. He succeeds **Robert Ford** who retired at the end of 1959.

★ ★ ★

Beauchamp

Davis

A new vice-president at United Steel Corp., Ltd., is **E. H. Beauchamp,** who will be in charge of the corporation's steel and aluminum warehousing operation. He is also general manager of United Steel Sales Ltd.

★ ★ ★

Engineer **Frank R. Petch,** P.Eng., enters the insurance field as he joins the engineering staff of Tomenson, Saunders, Smith & Garfat Ltd.

★ ★ ★

J. R. McGovern has been elected vice-president and general manager of Sola Electric (Canada) Ltd. He also has been re-elected to the board of directors and will be in charge of operations of the company's two Toronto plants.

★ ★ ★

Welwyn Canada Ltd. has appointed **Ken J. Davis** as assistant director of sales. He previously was general manager and sales manager of Renfrew Electric Co.

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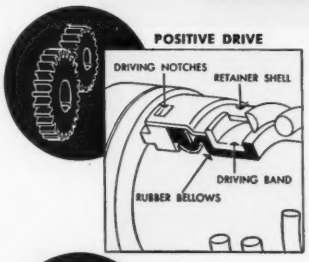

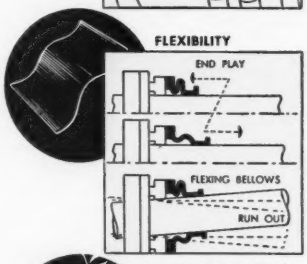

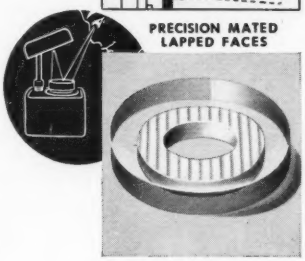

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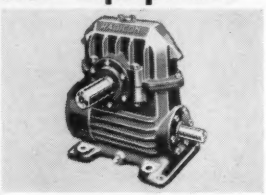

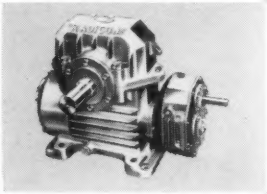

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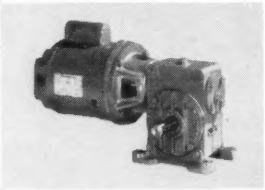

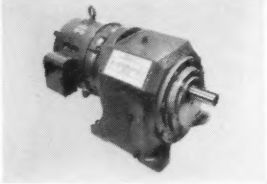

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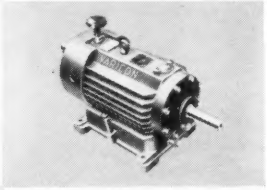

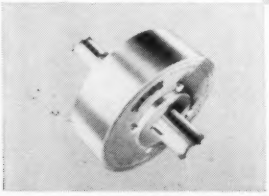

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Principles of Metal Casting, by R. W. Heine and P. C. Rosenthal, both professors of mining and metallurgy at University of Wisconsin. Publisher — McGraw-Hill, Toronto 4. 639 pages. Price: $8.95.

A helpful guide to the best foundry practice, giving detailed methods for successful pattern making, coring, sand conditioning, melting, pouring, cleaning and inspection. Presents information on the various types of cast irons, steels and alloys . . . treats their chemical composition, structure and properties . . . provides data on tensile, yield, shear and impact strengths, etc. Mechanical design engineers will find this book an assistance in all phases of the metal casting process. **300**

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Handbook of Practical Electro-plating, by T. M. Rodgers, past president of American Electro-platers Society. Publisher — Brett-Macmillan Ltd., Galt, Ont. — 332 pages. Price: $8.50.

This is an encyclopedic type book, with the topics arranged alphabetically from abrasives to zirconium plating. Covers all the actual practices of plating shops as well as the theory of plating. Ideal reference for engineers whose training has been in other fields. Each type of plating is described in terms of its industrial uses, equipment, operation and control. **301**

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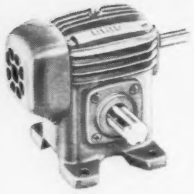
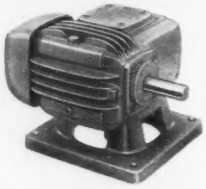

U Series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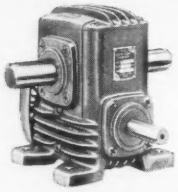
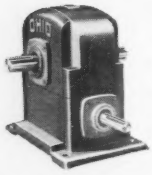
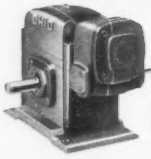
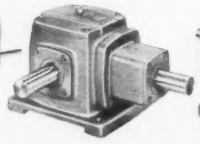
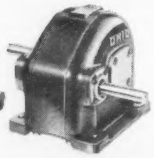

S Series

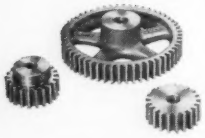
Non-Ventilated Models


Single Worm


Double Worm


Bevel Gear


Helical Gear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Keeping informed *continued*

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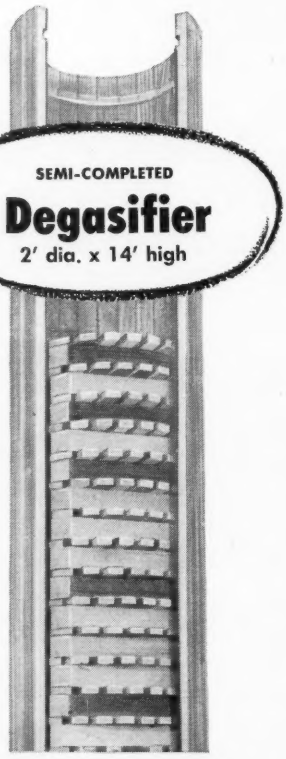

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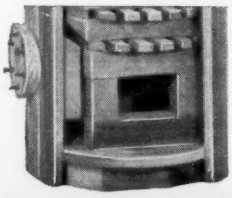

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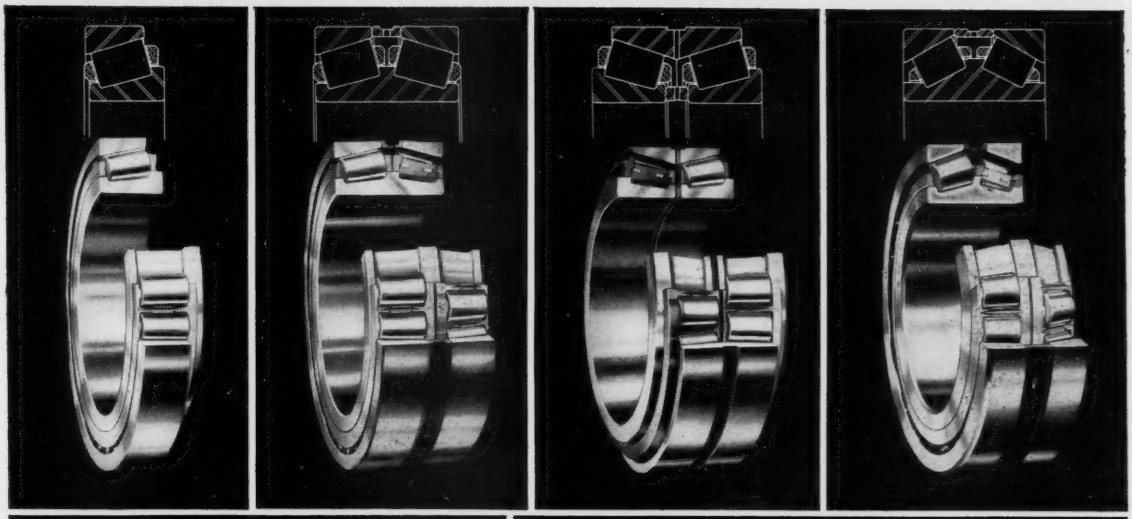

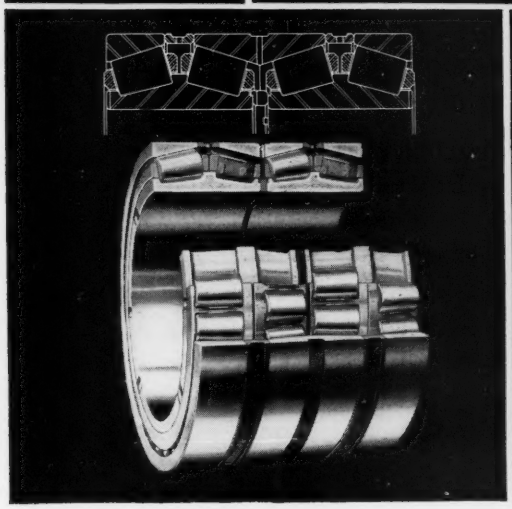

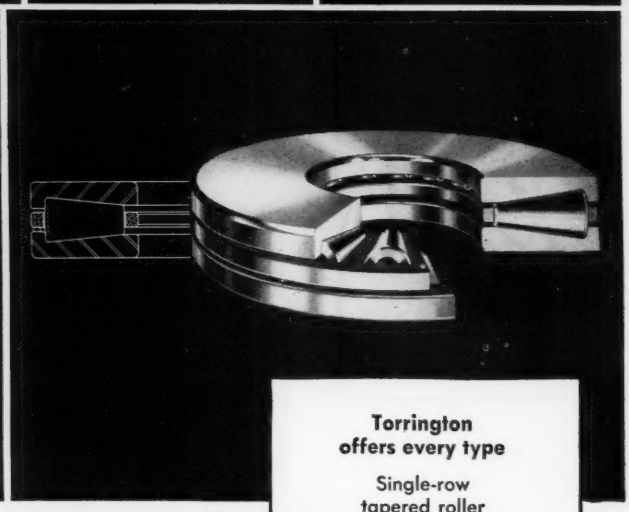

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Single-row tapered roller

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Two-row tapered roller, solid cone

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Two-row tapered roller, solid cup

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Patterned for performance... Torrington Tapered Roller Bearings

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There are single-row, double-row... four-row tapered roller bearings—all in regular or steep angle design for radial and thrust loads—and conical roller thrust bearings for heavy thrust loads. Each is designed for dependable service in its operation.

Whether your application calls for a catalog bearing, or one custom-built to your specifications, you can rely on Torrington for utmost precision of manufacture, quality material, advanced metallurgy... and engineering experience based on the manufacture and application of every major type of anti-friction bearing. **The Torrington Company, Limited, 925 Millwood Road, Toronto 2, Ont.**

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Every Basic Type of Anti-friction Bearing

TAPERED ROLLER • SPHERICAL ROLLER • CYLINDRICAL ROLLER • NEEDLE • BALL • NEEDLE ROLLERS • THRUST

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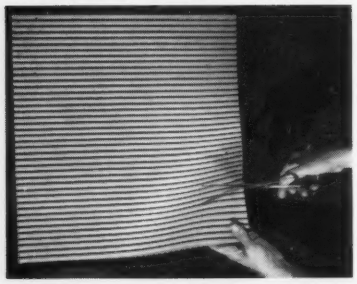
New products & materials

Reducing noise, vibration



Vibropads are a special corrugated neoprene pad (oil resistant) for the elimination of noise and vibration from high speed equipment. When placed under the equipment, no bolting down is required since no "creeping" or "walking" will occur. Pads are available in sheets 18 in. x 18 in. x ⅜ in. thick, with recommended loading of 50 lbs. sq. in. They are easily cut with hand shears. Suggested applications — lathes; milling machines; printing presses; office machines; air conditioning equipment; fans; transformers; motors; control panels. **Vibron Limited.** **330**

Manganese welding

A low hydrogen, iron powder electrode has been developed by **Lincoln Electric Co., of Canada Ltd.** for welding 12 to 14 per cent manganese steels.

Called Mangjet the electrode is suitable for building up manganese steel hardsurfacing deposits on either manganese or carbon steels and also for making joints between these metals. Electrode may be used on both ac and dc machines and is available in 5/32, 3/16 and ¼ in. sizes. **331**

Reverse phase voltage relay

A type CP relay, used to detect reverse phase connections of transmission lines, transformers, generators or synchronous condensers is now available from **Canadian Westinghouse Co., Ltd.**

The relay is described as a three-phase, contact making voltmeter. One set of relay contacts closes on three-phase overvoltage conditions while another set closes on three-phase undervoltage, loss of voltage, reverse phase connection or serious phase unbalance. Main contacts close 30 amps at 250 v dc, and carry this current for sufficient time to trip a circuit breaker. **332**

Electronic auto-collimator

An electronic auto-collimator capable of measuring the tilt of a reflective surface with respect to the auto-collimeter axis comes from **Keuffel & Esser Co.**

The new instrument is said to be ideal for checking flatness of surface plates, straightness of machine tool ways and run-out of precision bearings, and for monitoring drift of gyros. According to the company it reads angles directly to a sensitivity approaching 1/50 of a second. **333**

Heavy load chain

A roller chain, designed to handle heavy loads in industries where extremely difficult operating conditions are encountered, such as oil field rigs, construction, mining and quarry equipment, is a product of **Atlas Chain & Manufacturing Co.**

It is called Atlas Offset Side Bar Roller Chain. Feature is that the chain is made up of a series of identical links held together with cotter or rivetted pins. This makes removal or replacement of links a simple matter. **334**

Wound-wire porous metal

A wound-wire porous metal, for both filtration and nonfiltration uses, is now available from **Aviation Electric Ltd.**

Called Poroloy CS, it is wound by a high precision wire winding process into hollow cylinders or cones. Special shapes can be formed by cutting cylinders axially then opening and flattening them.

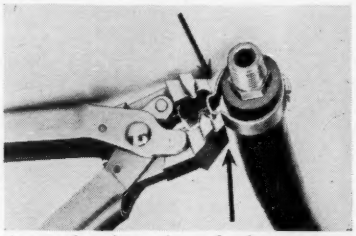
The wound wires are bonded with silver or copper braze at all contact points in continuous, controlled atmosphere furnaces. Brazing is followed with an electroless nickle plating in cases where a high corrosion resistance is needed. The standard product is designed for mildly corrosive conditions and temperatures up to 400 F. **335**

Toggle clamp

A new plunger-type toggle clamp with a swivelling handle, for use where clearance requirements do not permit using conventionally designed clamps, has been added to the standard line of De-Sta-Co clamps.

Designed for medium holding applications, the new clamp, designated Model 606, was developed by the **Detroit Stamping Co.** The handle swivels in a 220-degree arc and can be fixed in any position within this arc by a lock-nut located on the axis of rotation. **336**

Single lug hose clamp



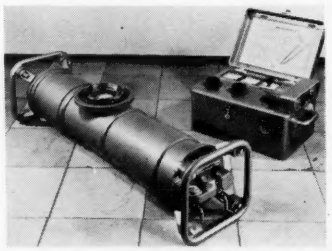
A one-piece hose clamp for low pressure hose and tubing has been developed by the Circle Clamp Division of **Cuyahoga Products Corp.** It clamps permanently with only one squeeze of a simple tool, and is easily accessible wherever used.

The clamp is a modification of the company's standard circle clamps, is designed for wherever low pressure hose and tubing is used. It has one U-shaped locking lug instead of the usual two or three on standard circle clamps. The single lug results in greater setting speed on the assembly line. **337**

Resin in rod form

Delrin acetal resin, a new thermoplastic material developed by duPont, is currently being made available in extruded rods up to three inches in diameter by the United States Gasket Company, Plastics Division of **The Garlock Packing Company.** The material has outstanding tensile strength, rigidity, fatigue life and resistance to creep and solvents at room and elevated temperatures. **338**

Portable x-ray unit



A portable, industrial X-ray unit, that is said to provide high penetrating power and excellent radiographic definition, is now available from **Phillips Electronic Instruments.**

Called the Norelco PG 300, the unit is completely self-contained. It is shockproofed, rayproofed and weatherproofed for outdoor operation. Safety devices are incorporated to prevent overload on tube. Light weight of the tubehead, only 231 lb, permits it to be hoisted to remote areas. **339**

Which of these
MODERN
Speed Nut
FASTENERS
will cut your costs?
(At least one of them certainly will!)
EXPAK"ION TYPES—for fast assembly in blind locations where there is access to one side only. Snap by hand into square holes.
FLAT TYPES—one piece, self-locking. Replace threaded nuts, lock washers and spanner washers.
COMPRESSION RINGS AND "C" CLIPS—for attaching plastic knob-to-shaft assemblies. Faster permanent assembly is assured.
PUSH-ONS—zip over unthreaded die-cast or plastic studs, rivets, nails, tubing or wire to lock parts securely.
"U" AND "S" CLIPS—for attaching metal, plastic or wood panels with a spring cushion. Eliminate holes in panels.
"J" TYPES—snap over edge of panels or into centre-hole locations. Hold themselves in place for blind assembly.
TUNING FASTENERS—for better, faster mounting of radio coil forms. Hold core in position and provide tension on adjustment screw.
"U" TYPES—perform same function as "J" types, used where full bearing on lower leg of the Speed Nut is required.
DART-TYPE CLIPS—dart portion compresses as it is snapped into hole, springs back to retain itself in place, or to lock panels together.
TUBULAR CLIPS—for use with unthreaded studs or rivets on attachments where there is access to front side only.
CABLE CLIPS—snap in place by hand and hold themselves in position by "heel and toe." Easily removed for servicing.
SPEED GRIPS—snap easily into bolt-receiving position without use of special equipment or skills; provide floating alignment.

The *profit*-conscious manufacturer is *cost*-conscious too!

Speed Nuts offer a tailor-made way to trim costs . . . and often improve quality into the bargain. They bring fastening up to date, and reduce costly hand operations to a minimum.

Speed Nut engineers will be glad to discuss your fastening problems and show how Speed Nuts can help you solve them.

More than 8,000 sizes and types are available . . . and if one of these won't cut your costs, we'll design one that will.

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WE MANUFACTURE_____

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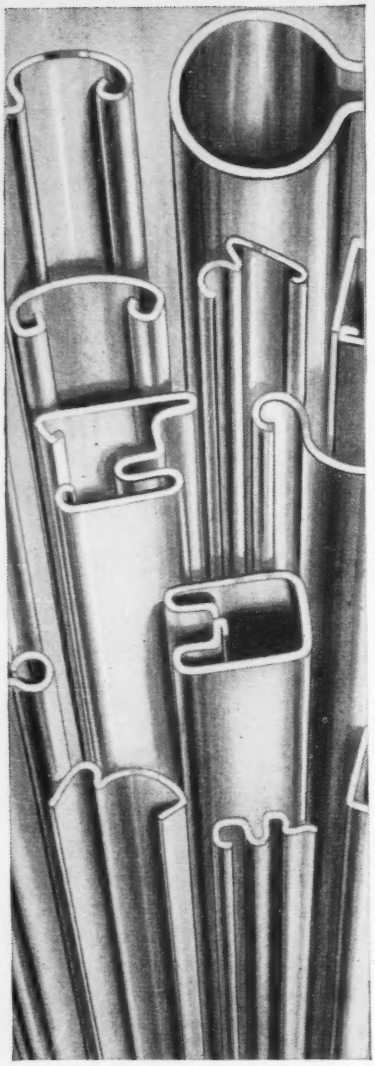

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Briefs

We note with interest . . .

New idea in photography from General Electric involves converting technical data or photographic images into electronic signal, reducing these to intensity variations in a beam of electrons and playing the beam across a three-layered film. Negative pattern is achieved by melting of thermoplastic skin . . . **One lever** control for tractor gear shifting does away with bumps and grinds. Speedy shifting is the secret. Unfortunately, control is not effective on teen-agers . . . **Giant machine** looking like a mechanized cathedral arch packs down snow firm for use as an aircraft runway . . . **Bridge design** engineers are getting together as a technical group of the Canadian Good Roads Association. Prime purpose — to study common problems . . . **An aquarium** is to be built by the Calgary Brewing and Malting Co., Ltd., we hear. Fearing for the morals of the fish we made enquiries but have been assured that the tanks will be filled with water only . . . **Displaying** a voracious appetite for shale and limestone a 60-ton mechanical mole has eaten out a two mile tunnel beneath the Humber River, Toronto. Eleven feet in diameter, the big bore will serve as a trunk sewer . . . **Bulbous stern,** below the shaft line, built into a 45,000 ton tanker is designed to improve flow of water around the circumference of the propeller . . . **Canadian** Westinghouse has won a multi-million dollar contract to engineer and manufacture a nominal 25,000 kw gas-turbine generator. Engine will be the first ever built in Canada . . . **Here's a home** that can be flown. Frame is aluminum tubing, covering a double layer of Terylene taffeta that sandwiches insulation of fibreglass. It is weatherproofed with a polyurethane coating. Idea is good for surveyors, hunters and people who want to get away from it all . . . **A Calgary company** that developed a device for resetting bowling pin is suing two Toronto companies for patent infringement. Damages claimed—$500,000 . . . **Did you know** that ultrasonics can drive rats from a ship, measure fat on livestock and find fish in the sea? . . . **People who hunt** semiprecious stones as a hobby are called Rockhounds, their children — Pebblepups . . . **Computing Devices** of Canada Ltd., has been awarded a $4 million NATO contract for an aircraft navigation set it designed . . . **"Railway Sinks Sub"** makes a fine headline but no secret weapons are involved. Model of the British nuclear-powered cargo submarine Moby Dick was dam-

(Continued on page 78)

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PANEL MEASURING INSTRUMENTS

PORTABLE AND LABORATORY INSTRUMENTS

ELECTRONIC INSTRUMENTATION

Only a complete Canadian instrumentation facility can offer the kind of service Canadians need. Bach-Simpson Ltd. *is* complete — in research, design, tooling and manufacture.

If our standard line of instruments, complete as it is, won't meet your requirements, ask us to demonstrate the unique combination of skills we can offer in the design of specialized instrumentation to meet your specific problem.

Others have, and have been completely satisfied!

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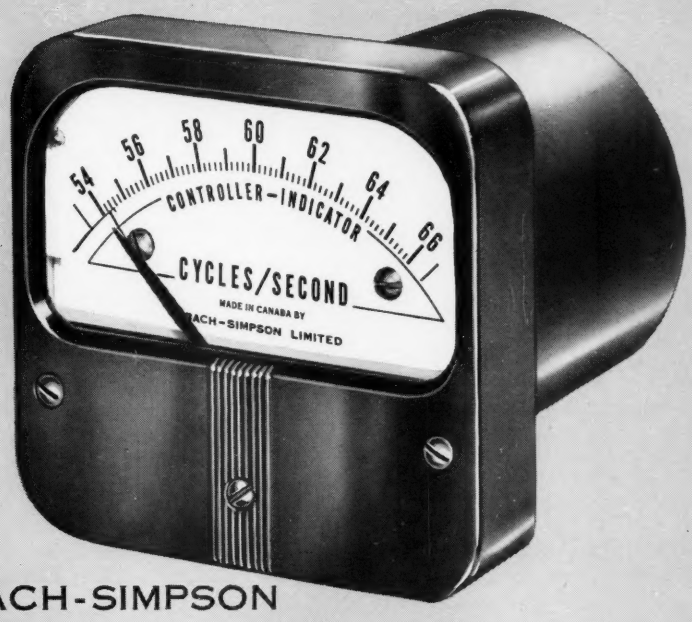
NEW

THE COMPACT CONTROLLER



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Controller-Indicators

offer sampling of pointer position at regular intervals, with positive contacting in the case of a shift of the measured quantity outside of preset limits. Contact pressure is produced by a solenoid, and is therefore independent of meter torque. Circuits of the integral primary relays are actually closed by heavy motor-driven contacts, rather than by the pointer contact itself.

Frequency, voltage, current, temperature — in fact, any quantity which can be indicated on a switchboard instrument — can be accurately and reliably limited or programmed, with simultaneous indication. A variety of sampling intervals and a wide range of contact arrangements are available, and slave units, as well as self-contained types for independent operation, are standard.

In addition, a full line of switchboard meters, compatibly styled and featuring the anti-parallax pointer and scale combination employed in the Controller-Indicators, makes possible a completely integrated panel design.

The Bach-Simpson Frequency Controller-Indicator received the I.R.E. Award for the most outstanding new Canadian component exhibited at the 1959 I.R.E. Canadian Convention.

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Briefs *Continued from page 76*

aged in transit on a Canadian railway . . . **Coming soon** — plastic or nylon bearings for automobile steering and front-end assemblies. Will save a lot of grease . . . **Ontario's Queen** Elizabeth Way is to get another skyway. It will span the Welland Canal near St. Catharines . . . **14,400 gallons** in a single tank car is a big haul. CNR did the job with a new colossus that may soon enter regular service if trans-Canada tests work out . . . **Cost cutting** is feature of space saving cellular steel floor that provides built-in air conditioning through expanded cells . . . **A computer**, well versed in the three R's, is being rented by Canadian Oil to handle its credit cards. Machine not only reads but "writes" with punch cards, too . . . **It's made of** two pieces of rigid polyethylene, a reamer, with spiral cutouts, and a pitcher. What is it? It's a juice squeezer. Took a Toronto designer two years to perfect . . . **Winner in** a design competition for Winnipeg's new city hall is the Winnipeg firm of architects Green, Biankstein, Russell and Associates . . . **Car exhaust** mufflers may soon be finished with porcelain enamel. Replacements should be finished with, too, since ceramic material is resistant to acids, corrosive gases and moisture . . . **Also new** for automobiles is a carburetor air filter cartridge of urethane foam. They're already installed on several 1960 models . . . **For the outdoor** man with an outboard: single-lever remote control with moving parts of molded nylon. First of its kind to be made in Canada it's called the Whitney Automatic . . . **Two big vault** doors have been installed in a new Bank of Montreal building. They are 10 ft. high, 42 in. thick and weigh 33 tons each. And what will the burglars do now, poor things? . . . **Congratulations** to Ralph W. Diamond on becoming an honorary life member of the APE of B. C. . . . **Sperry is building** a "sea". It measures 400 by 200 ft. and is 25 ft. deep. Idea is to test underwater detection devices such as SONAR . . . **American Society** of Tool Engineers will hold its Tool Show and Annual Convention at Detroit this year. Dates: April 21-28 . . . **Another show,** the Corrosion Show, will be held March 14-18 at Dallas. At the same time there will be a conference of corrosion engineers . . . **And still another:** the Atomic Exposition and Nuclear Congress to be held April 4-7 at the New York Coliseum . . . **Make a note,** too, of May 23. That's when the Design Engineering Show opens in New York. And watch DE for all the details . . . **Canadian Atomic** Energy Conference in Toronto recently was thrown open to the public. All praise to the committee who decided to do this. Too often affairs of public importance are made the private preserve of a particular group . . . **Quicker crops** without conventional greenhouses are promised with a polyethylene tunnel that can be set up in the field. Douple plastic sheets are stretched between aluminum frames forming Quonset style sections. Tunnel is big enough for farmers to work under . . . **Drivers looking** for "no left turn" signs will be saved a lot of eyestrain if a new Canadian invention is introduced. Purple lights will indicate illegal turns . . . **Canadian Curtis** Wright plan to manufacture an air car in Canada this year, we see. Cost for a four-passenger model: $17,800. Even flying carpets come cheaper than that . . . **New consultant** company in the research field is M. Levy & Associates of Ottawa. Firm was formed by Dr. Maurice Levy, technical consultant to the Canadian Post Office . . . **Brief Talepiece:** What next we wonder? Now it's nonalcoholic champagne specially designed for teenagers and nondrinkers. Comes with all the trimmings, gold foil, wired cork, green bottle and all. But some dancing girls we know would be very hurt if we filled their slippers with anything but the real McCoy. ★

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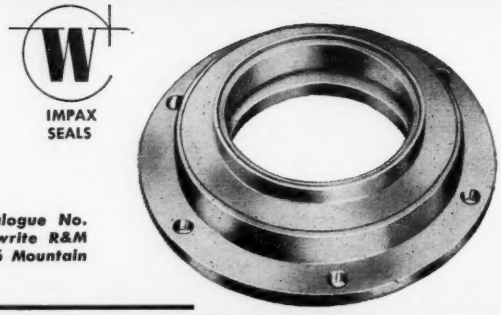

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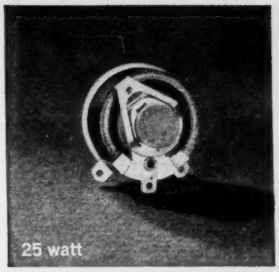

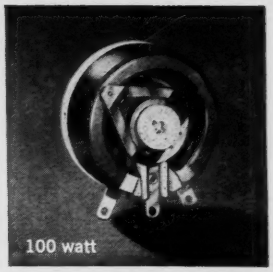

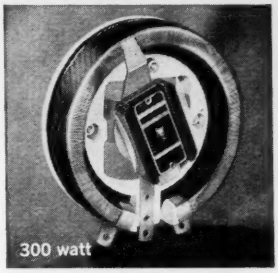

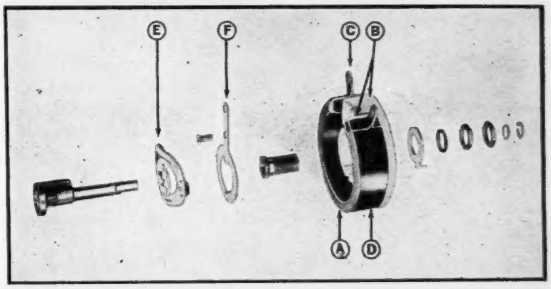

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Ideas round-up

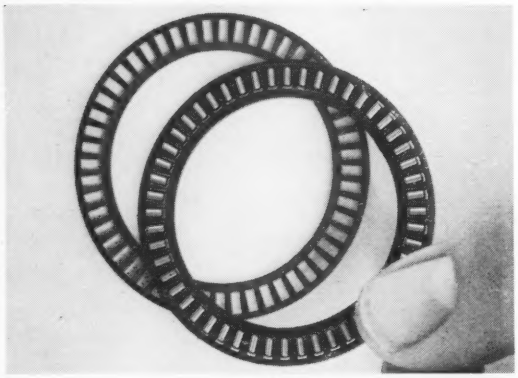
Solves blueprint blues

How much money and patience goes into hand-lettering specifications and data onto blueprints? How much storage space do bulky blueprints occupy? If your company uses blueprints at all extensively you probably know the answers.

An American aircraft company faced up to the blueprint problem and came up with a system of separating the "picture" and the written data while keeping them under the same reference number. Production of the picture print remains the same but all written information will now be documented in handy loose-leaf folders. Both sets of documents will be available in separate packages and users need draw only the information needed for a specific job.

Changes in data, in themselves a time consuming item, are handled easily. In the new system they call simply for a replacement of a looseleaf page. For picture prints, changes will continue to be attached until it is economical to reprint the drawing. Source — *Boeing Airplane Co.* **340**

Bearing cages break safely



New use for glass-filled nylon is in the manufacture of cages for thrust bearings. They can be made for either roller or ball bearings, in a wide range of sizes.

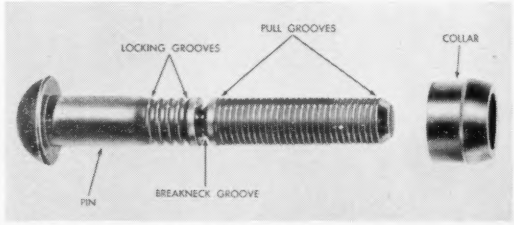
Principal advantage of using this material is that tramp metal invading the bearing area imbeds itself in the plastic. This removes ordinarily loose metal particles from circulation, greatly reducing bearing abrasion and consequent wear of adjoining metal surfaces. Nor will there be metal particle entrainment if the bearing cage should fail.

Other advantages are reduction of assembly time (the bearings are simply popped into molded cavities) and savings on material. The material is said to have excellent wear resistance and requires no lubrication. This should give savings in both maintenance and downtime. Source — *Garlock Packing Co.* **341**

Fastener switch makes money

A change in fastener specifications has produced a 45 percent reduction in costs in galvanized sheet assembly operations for the manufacturer. The company switched from 3/16 in. solid rivets to 3/16 in. Huckbolt fasteners for assembly of large diameter galvanized ducts, elbows and covers used in commercial and industrial painting systems.

In the previous operation, using solid rivets, one man hammered while a second held a bucking bar behind each rivet. The new method permits one man to do the work alone. The fasteners are installed with lightweight pneumatic power tools. Installation rate is about



double that possible with solid rivets. Source — *Huck Mfg. Co.* **342**

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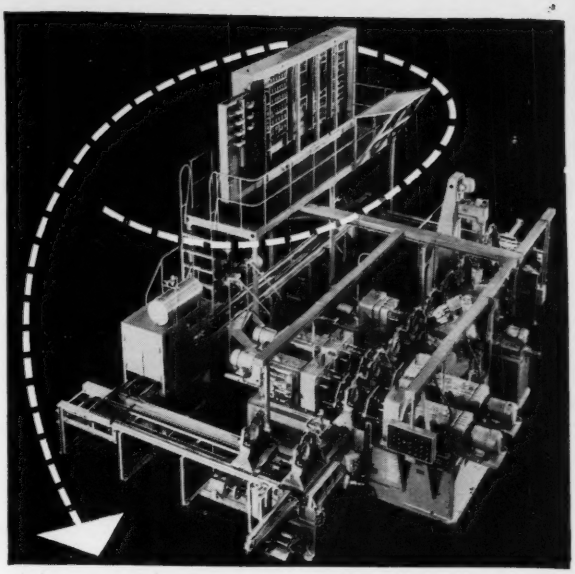

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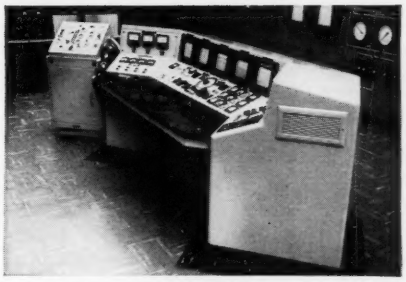

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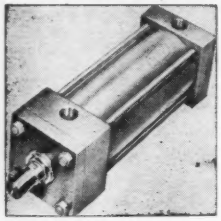

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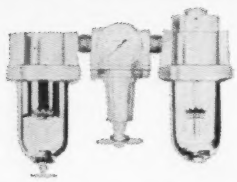

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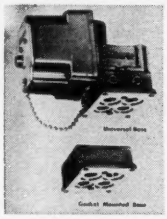

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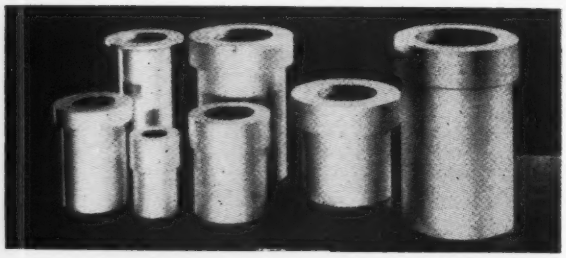

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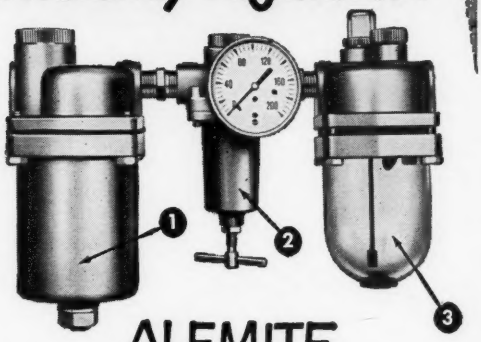

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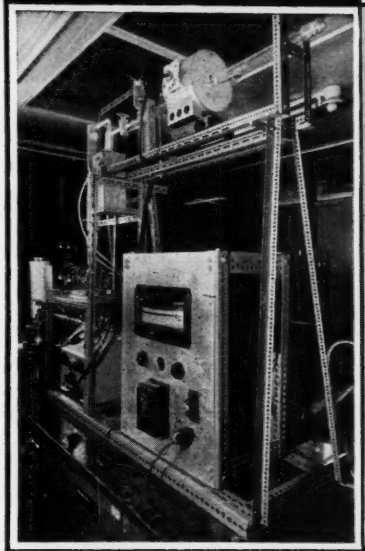

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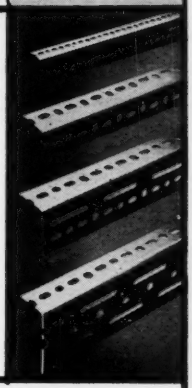

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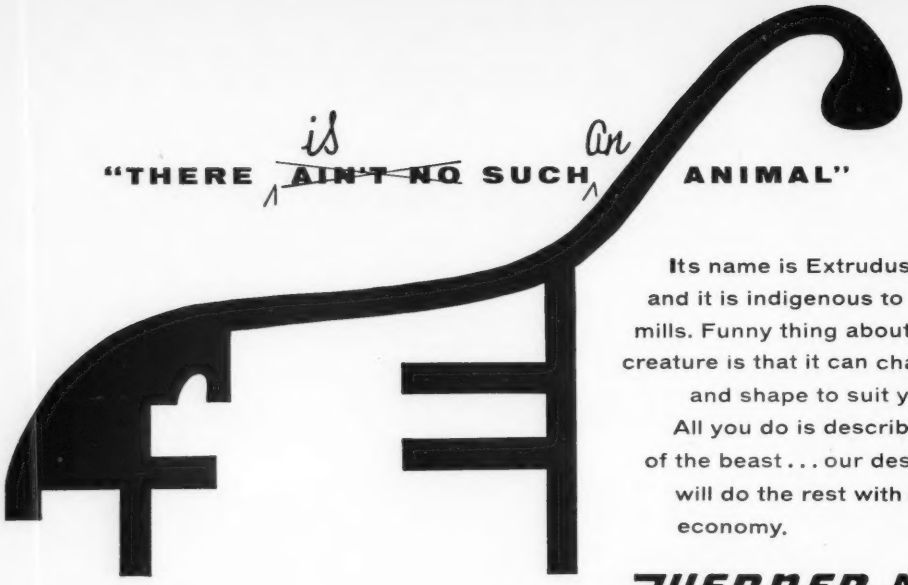

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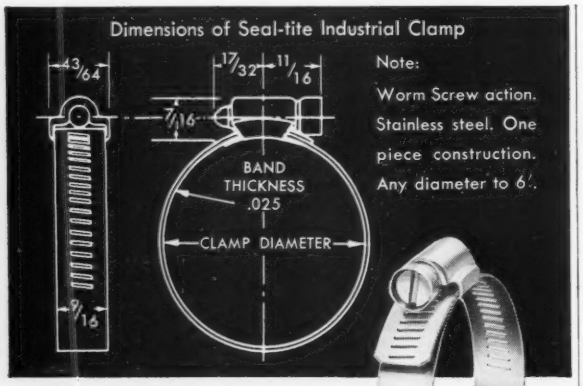

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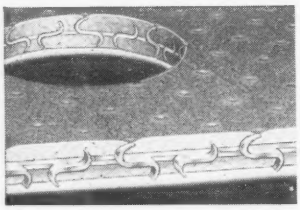

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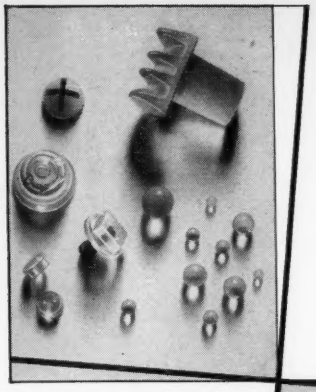

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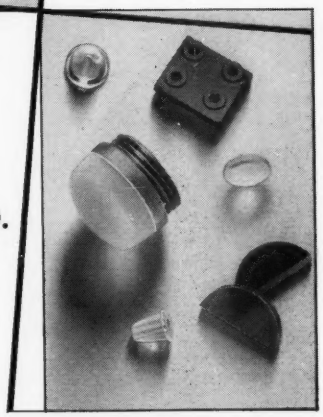

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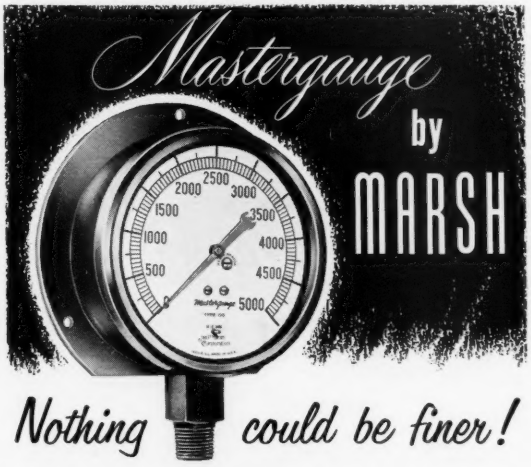

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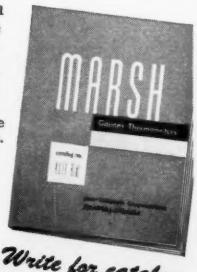

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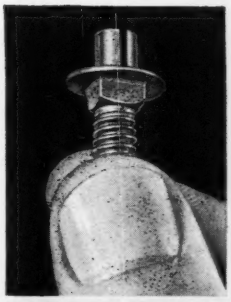

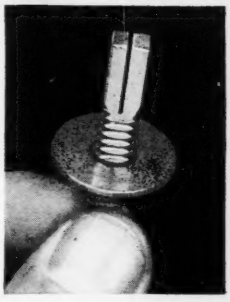

For further information about standard or special fasteners contact any Stelco Sales Office. Also, ask for Stelco's quarterly bulletin on fastener developments "Bits and Pieces".

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* Mr. F. I. Baine represents Stelco in the Montreal area. He is one of a group of representatives specially trained to bring personal interest and expert attention to your needs in special fasteners.

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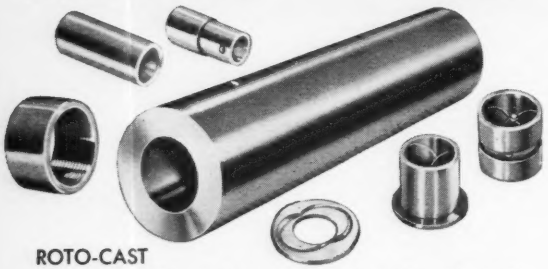

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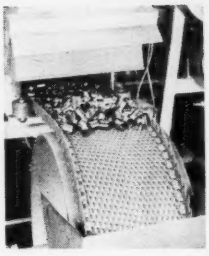

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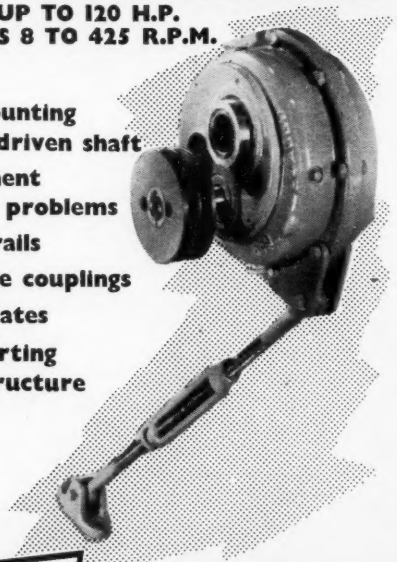

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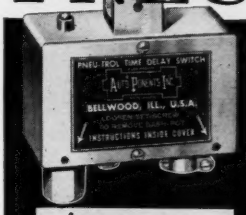

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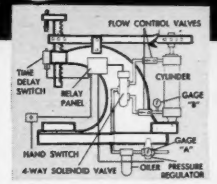

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Editorial

Promote Canada by using copper and brass

... aid to the designer is available for the asking

Copper was the first metal used by man, according to historians. He found it on the surface of the earth, refined by the workings of nature, as far back as the Stone Age, around 13,000 B.C.

He was no doubt impressed by the ease with which he could work this "new" material — a knife or axe could be fashioned without the production difficulties he was experiencing with stone.

In Canada, it is recorded that copper was first discovered at Cape d'Or, Nova Scotia, in 1604 by an exploration party under Champlain. That is, it was first discovered then by the white man, for Eskimos and Indians are known to have used and traded copper instruments long before that.

Copper mining commenced in Canada about 1847 at the Bruce Mine in the Algoma district. Statistics on copper production were first kept in 1886, and in that year 1752 tons were made.

Stepping forward to the present, we find that Canada ranks fourth among the free world's copper producing countries. Average production for 1958-9 totaled 350,000 tons.

Canada does not approach the point where all the copper it produces is used within its borders, and therefore exports large tonnages to various parts of the world. This does not mean that Canadians are not heavy users, for in fact, about 40% of Canada's production is consumed by domestic manufacturing plants and foundries. But the percentage could—and should —be much higher.

Ray Wardell, manager of the Canadian Copper & Brass Development Association, in speaking recently to the JC's at Oshawa, Ontario, said, "The Canadian copper and brass industry looks to the future with confidence, being assured of continuing ample supplies for its mills and foundries." But what of the applications? What of the users? Without customers, what will the basic producers do?

The answer is in the hands—and creative abilities—of the Canadian designers.

Some materials, such as concrete, lend themselves to only one basic application and production method. Other materials, and copper is the prime example, are more versatile. This versatility permits its use in many forms, from pure copper to complex alloys, from sheet to wire, from electrical conductor to decorative jewelry.

The Canadian Copper & Brass Development Association, now just a little over one year old, has already established itself as a major contributor to the Canadian way of life. The Association provides the machinery for a united effort by its members—an effort aimed in part, to assist the design engineer.

Indeed, one of the major functions of the Association is to provide technical assistance on problems of design, manufacture and fabrication. Whether one or a million pounds of copper is involved, we are certain the CCBDA is still interested in the successful conclusion of any project. Since the Association is a member of the international associations, no problem is ever too big, or too small, to be handled.

Copper has many basic advantages, as exemplified by the articles in the earlier pages of this publication, including electrical conductivity, thermal conductivity, resistance to corrosion, ease of fabrication and attractive finishing possibilities.

Canada has an adequate supply of copper.

CCBDA has the technical know-how.

The future of Canadian copper is in the hands of the designers.

CCBDA's Wardell and editor

Doug Kaill

ASK ANACONDA

for the answer to your metal problems

AIR COILS MFG. CO. LTD. did...

When heating and cooling coils were required for air conditioning units in the Navy's destroyer escorts, specifications were rigid.

For example, tubes had to have superior resistance to corrosion, particularly from salt brine. It was necessary to minimize the danger, through leakage, to vital electronic equipment. Every precaution had to be taken against the possibility of repairs in hard-to-reach, cramped quarters.

Air Coils Mfg. Co. Ltd. was awarded the contract. Anaconda supplied the chosen metal—cupro-nickel. In the photograph, Mr. E. G. Pullen (left) President, Air Coils Mfg. Co. Ltd., Mr. H. S. Litchfield (right) Vice President in charge of Design and Operations and Mr. W. C. Farrow (centre) Anaconda Sales Representative, examine blueprints for one of the installations.

Here is another example of how Anaconda co-operates with Canadian industry in the solution of production problems through the application of copper and its alloys.

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C-5940

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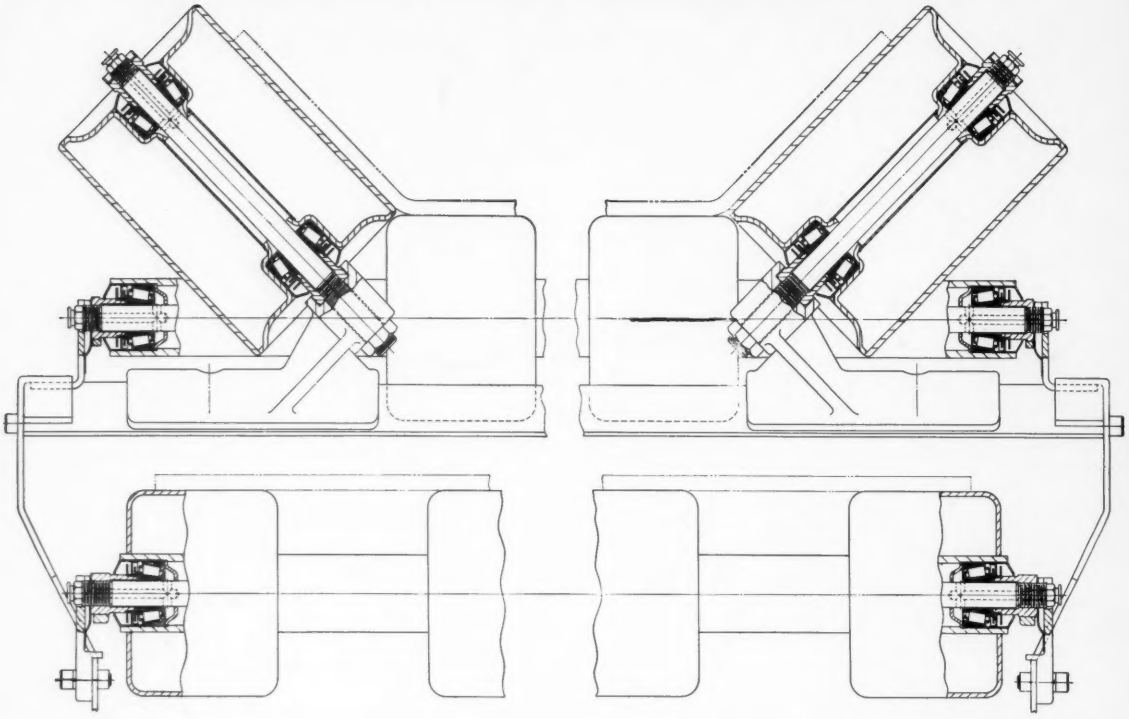
How Jeffrey mounts new GT Idler Axles and Rolls to cut conveying costs



In designing their new GT belt conveyor idler specifically for the grain industry, Jeffrey Manufacturing Company Limited aimed to provide all the extra trouble-free and long life benefits of modern all-steel idlers. To assure this steady, smooth, low-cost operation, Jeffrey equips the GT's return idler axles, flat carrying idler axles and concentrator rolls with Timken® tapered roller bearings (shown above).

Timken bearings assure better machine performance, longer bearing life with minimum maintenance because: 1) They hold shafts concentric with housings, making closures more effective in keeping lubricant *in,* dirt *out.* 2) The tapered construction of Timken bearings lets them take radial and thrust loads in *any* combination.

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